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ORIGINAL ARTICLES.

I.—Notes on British Dinosaurs.[1] Part V: *Craterosaurus* (Seeley).

By Dr. Baron Francis Nopcsa.

In the course of my researches among British Dinosaurs the kindness of Dr. J. E. Marr and Professor T. McKenny Hughes has enabled me to investigate closely the fragmentary bone which Professor Seeley described in 1874 under the new generic name of *Craterosaurus*.[2] Although the systematic position of the specimen had remained problematical from the day of its discovery, nevertheless the hope was entertained that in consequence of our present more ample knowledge of Dinosaurs and fossil reptiles in general, it might now be possible to determine the exact nature of this apparently most interesting fossil. The result was rather unexpected, for it became clear that what Seeley supposed to be the base of a cranium was nothing else than the neural arch of a dorsal vertebra showing the greatest resemblance to the corresponding element in *Stegosaurus*.

To prove the Stegosaurian affinities of *Craterosaurus* in a striking and convincing manner, two drawings of the fossil are given side by side in Fig. 1, together with corresponding figures of an American Stegosaurian vertebra in the British Museum (Natural History). As shown by the figure (Fig. 2) of the American *Stegosaurus*, Seeley's supposed occipital condyle is a process formed by the two fused post-zygapophyses (*pt.z.*), and the so-called base of the brain-cavity of *Craterosaurus* corresponds exactly with the spoon-like projection that is produced in Stegosaurs by the fusion of the two præ-zygapophyses.

In consequence of the concrescence of the right and left anterior and posterior zygapophyses, the cleft that is usually visible between the zygapophyses of Reptilian vertebræ, but is already very much obliterated in *Omosaurus Lennieri*,[3] is practically reduced to nothing in *Craterosaurus*, so that a curious kind of zygosphenal articulation is developed.

Besides the præ- and post-zygapophyses, one can also determine in *Craterosaurus* the position of the parapophysis, the diapophysis, a part of the neurapophysis, and even the position of the neural canal. The parapophysis (*pa.*) is formed in *Craterosaurus* as in *Stegosaurus* by a shallow well-marked depression, and represents the region which

[1] Part I, *Hypsilophodon*, Geol. Mag., 1905; Part II, *Polacanthus*, loc. cit.; Part III, *Streptospondylus*, loc. cit.; Part IV, Geol. Mag., 1911.

[2] H. G. Seeley, "On a Lacertilian Cranium from the Potton Sands": Quart. Journ. Geol. Soc., vol. xl, pp. 690–2, 1874.

[3] Nopcsa, "*Omosaurus Lennieri*": Bull. Soc. Géol. Normandie, tom. xxx, p. 11, anné 1910 (1911).

Seeley considered to be the surface of attachment for the alisphenoid. The fractured surface of the diapophysis (*d.*) is situated above and laterally of the parapophysis, where Seeley located the ex-occipital and the periotic; and the neural spine (*n.*) rose from the blunt, compressed, and broken ridge, which is well shown in Fig. 2 of Professor Seeley's drawings, though not specially mentioned.

All the bone of the vertebra of *Craterosaurus* situated below the zygapophyses corresponds to the column-shaped part of the Stegosaurian dorsal vertebræ between these and the neural canal. The more dense nature of the tissue at the bottom of this column-like part that was supposed by Seeley to indicate the vicinity of the pterygoid suture of the basisphenoidal hypapophysis, indicates according to our new interpretation the proximity of the neural canal, for in all Dinosaurs the walls of this canal are characterized by dense bony tissue.

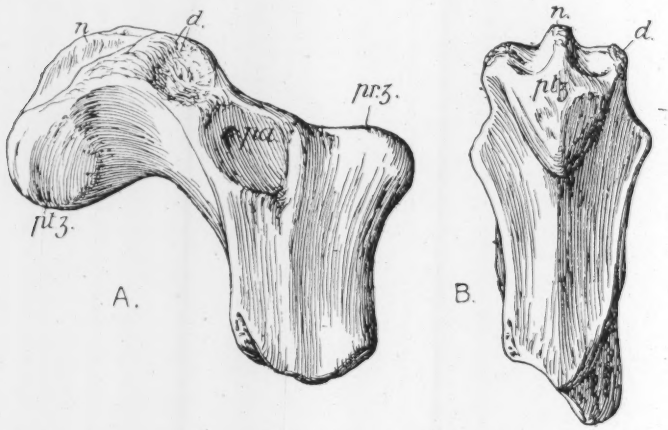

FIG. 1. *Craterosaurus pottonensis*, Seeley; part of neural arch in right side-view (A) and back view (B), one-half nat. size. Lower Greensand: Potton. [Type-specimen in Sedgwick Museum, Cambridge.] For lettering see Fig. 2.

A curious feature worthy of note is that in the middle of the column-like part, where most Stegosaurians show spongy bony matter, our fossil is perfectly hollow. Two irregular openings with fractured margins, the uneven surface of the hollow itself, and the much worn and rolled nature of the whole specimen suggest, however, that a great part of this cavity, if not the whole of it, may be due to post-mortem decomposition. In this case the influence of plant-roots, grass, moss, and water penetrating into small natural cavities of bones lying on the surface of the ground needs specially to be taken into account.

Having decided the anatomical character and general systematic position of the type-specimen of *Craterosaurus*, its generic position has to be considered. The unusually high position of the zygapophyses from the neural canal at once separates our fossil from

Scelidosaurus, from all well-known Acanthopholididæ (viz. *Polacanthus*, *Acanthopholis*, *Struthiosaurus*, and *Stegoceras*), from the Nodosauridæ (like *Ankylosaurus*),[1] and even from the Stegosaurid genus *Omosaurus*. Altogether *Craterosaurus* shows a striking resemblance to the genus *Stegosaurus*, and were it not for the fact that it seems hazardous to determine the exact position of so poor a "medal of creation", and that no Stegosaur has ever been found in so young a deposit as the Potton Sand, *Craterosaurus* might be considered as a synonym of

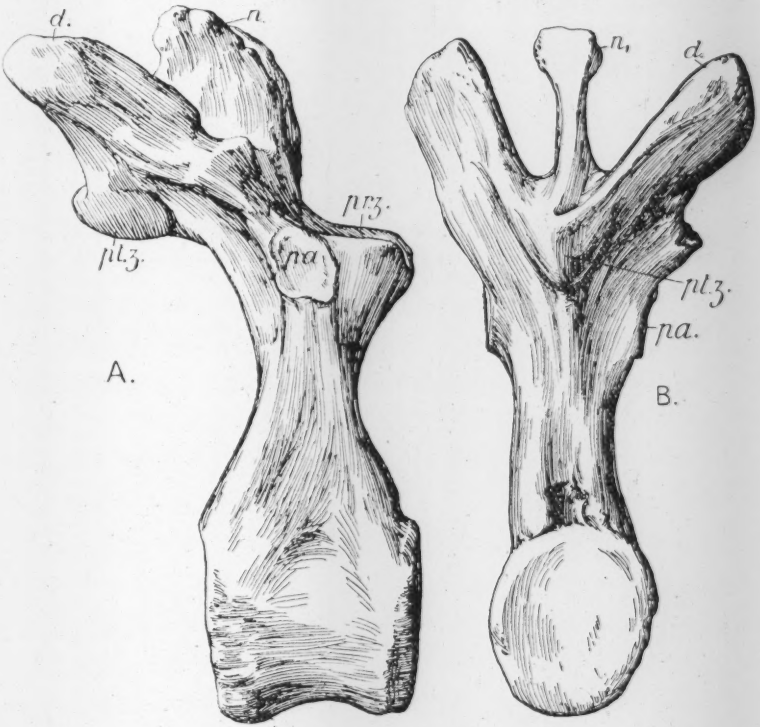

FIG. 2. *Stegosaurus* sp.; dorsal vertebra in right side-view (A) and back view (B), one-quarter nat. size. Upper Jurassic: Medicine Bend, Wyoming, U.S.A. [British Museum, No. R. 3216.] *d.* diapophysis; *n.* neural spine; *pa.* parapophysis; *pr.z.* præ-zygapophysis; *pt.z.* post-zygapophysis.

Stegosaurus; under the circumstances, however, it seems best to retain provisionally the name given by Seeley.

Great as Professor Seeley's error in the determination of *Craterosaurus* seems to be in the light of our present knowledge, it must be remembered that the fossil was described at a time when one knew

[1] The difference between the Acanthopholididæ and the Nodosauridæ (= Ankylosauridæ) is best seen in the structure of the cranium. Details will be published on some other occasion.

scarcely anything about extinct land reptiles. Nothing shows better how justified Seeley was in 1874 in considering the fragment of *Craterosaurus* to be part of a skull than the fact that since the original description, so far as I am aware, the cranial nature of *Craterosaurus* has never been questioned, at least in print. Had Seeley with the evidence then at his disposal originally described *Craterosaurus* as a neural arch of a dorsal vertebra, probably several of his learned colleagues would have supposed him to be mistaken. As a striking example of the great difficulties that the founders and pioneers of modern palæontology encountered in their early days, *Craterosaurus* thus possesses more than usual interest.

II.—The Uppermost Silurian and Old Red Sandstone of South Staffordshire.

By W. Wickham King, F.G.S., and W. J. Lewis, B.Sc.

(*Concluded from the October Number, p. 443.*)

2. *The Downton Castle or Yellow Sandstones* (see Figs. 2 and 3).—These occur at Lye and Turners Hill, but the best sections are at Saltwells. There the lowest beds are 10 feet of brown yellow and blue soft sandy mudstones (see Fig. 2, E^a), seen resting on the Ludlow Bone-bed, north of the Tram Bridge. Like the same zone at Ludlow, they are practically unfossiliferous.

To the north of this section there are some W.S.W. to E.N.E. faults that have let down some yellow Downton Sandstones which are studied best at "the (canal) Basin section" and Brewin's Tunnel.

The bottom of the Basin section is dolerite. Above it is this sequence:—

		ft.	in.
E^a	Greenish-yellow gritty hard sandstones: *Lingula Lewisii* (medium species), very abundant throughout	5	10
	Flaggy green sandstones	2	10
	Rubbly green and some yellow sandstones with many *L. Lewisii* (medium species)	4	9
	Yellow sandstone	1	6
	Rubbly light-green shales. *L. Lewisii* (smaller species) and fragments of fish scales	1	0
E^b	Very dark-green shale. *Platyschisma helicites*, *Modiolopsis complanata*, *L. minima* (rare), *L. Lewisii* (smaller species) very common	1	0
	Above the last there are 15 feet of yellow Downton sandstones with *Orbiculoidea rugata* and *L. minima*. On the south side of Brewins Tunnel the *Platyschisma* shale crops out immediately under the yellow sandstones which dip E.N.E. 31°.		
	Here the section continues thus:—		
E^c	One band of massive yellow sandstone with a fucoid bed at base. *L. minima* (common)	36	0
E^d	Fissile light-green shales 8 feet, passing into alternations of light-green shales, and rusty-red marly sandstones. *L. minima*	16	6
		69	5
	Add the lowest part of E^a at Tram Bridge	10	0
	Total of E exposed	79	5

The only Brachiopoda, we find, in E^a and E^b are *Lingulæ*. Mr. Lightbody at Ludlow "found *L. Lewisii* in the Upper Ludlow Series, but rarely; and near the top of that series abundance of another form, rather smaller, which he would be disposed to regard as *L. Lewisii* if that species had not been so rare in the Upper Ludlow".[1] A Eurypterid from E^b kindly examined by Dr. Bather is, he thinks, probably *Eurypterus pygmæus* (Salter).

At the basin section, Saltwells, E^a is crowded with *Lingulæ* as large as $\frac{8}{10}$ by $\frac{6}{10}$ of an inch, which are identical in form with *L. Lewisii*, but are much smaller than the *L. Lewisii* that occur in the Aymestry Limestone. They continue to the top of E^a.

In E^b a still smaller form of *L. Lewisii* is common, two of which measure $\frac{11}{20}$ by $\frac{8}{20}$ and $\frac{10}{20}$ by $\frac{7}{20}$. There are also *Lingulæ* which are rotund, for the two sides are not, as in *L. Lewisii* and *L. cornea*, fairly straight, but bulge out in a marked and distinctive manner. They are like those figured as *L. Symondsi* by Mr. Davidson in the *British Silurian Brachiopoda*, pl. iii, figs. 8, 9. *L. Symondsi*, so far as we are aware, has not, however, before been recorded at such a high horizon. Our specimens, out of E^b, gradually diminish in size and become elongated. The smallest and most elongated correspond with Mr. Davidson's dimensions and description of *L. minima*.

In South Staffordshire *Lingula Lewisii*, in its smaller forms, reaches E^b, which is a higher horizon than is recorded in the Ludlow district. Also *Orbiculoidea rugata*, which at Ludlow is rare in D^e, is found at Saltwells in E^c; and *R. nucula* and *O. elegantula* occur in D^e.

3. *Temeside or Eurypterus Shales* (see Fig. 4).—The magnificent section at Brewins Tunnel continues, at the same dip, uninterruptedly thus:—

		ft.	in.
	Yellow-white quartzitic sandstone with black markings	1	9
	Purple and green shales. *L. minima*, *L. cornea*, and Eurypteridæ	3	0
	Rusty-red marly sandstones. *L. cornea*	3	9
F^a	Light green-yellow soft sandstones. *L. cornea* and *minima*	10	3
	Rubbly green shales and marls with some micaceous purple shales. *L. cornea*, Eurypteridæ, *Cephalaspis Murchisoni*, *Onchus*, *L. minima*, etc.	5	0
F^b	Bone-bed limestone. *L. cornea* and many fragments of Eurypteridæ		4
	Green shales	3	5
F^c	Flaggy sandstones	2	0
	Red shale		6
F^d	Bone-bed limestone. *L. cornea* and many fragments of Eurypteridæ		4
	Green shale		$4\frac{1}{2}$
F^e	Calcareous yellow-green micaceous grit		$1\frac{1}{2}$
	Green shale	2	6
F^f	Calcareous yellow-green micaceous grit. *L. cornea*		2
		33	6

The two calcareous yellow-green grits are similar to the beds which occur in the vicinity of a bone-bed limestone where it passes either

[1] *The Silurian Brachiopoda*, pp. 35, 36.

horizontally or vertically into calcareous sandstone. They form two harder ribs in the midst of the softer material. The Temeside

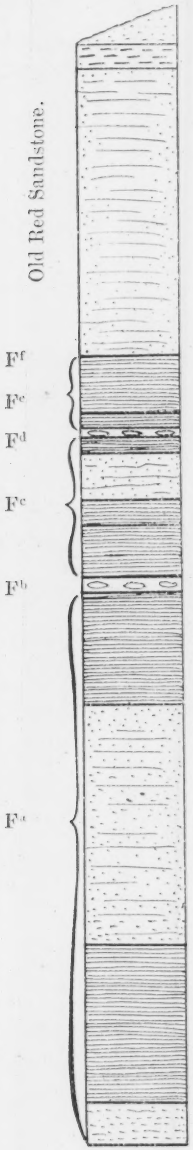

FIG. 4. Section at Brewin's Tunnel of Temeside Beds and some of the overlying strata. Scale 8 feet = 1 inch.

Bone-beds and shales occur along the west side of the reservoir, and here *L. minima* occurs abundantly within a few inches of F^b.

We divide E and F where *L. cornea* first occurs, though they might be regarded as one gradual transition from Silurian to Old Red Sandstone conditions.

Miss Elles and Miss Slater recorded two important palæontological changes in the uppermost Silurian of the Ludlow district, and we find the same at Saltwells.

At Saltwells the two great breaks are at the Ludlow Bone-bed and the Temeside Bone-beds. Below the former Brachiopoda abound, whilst above it they are rare, except *Lingulæ*. At and below the calcareous yellow-green grits and two Temeside Bone-bed limestones there is ample palæontological evidence; whilst above them the strata become thick purple or light-green or blue marls and highly micaceous purple and light-green sandstones, in which it is difficult to find fossils. We think we are justified, on these grounds, in regarding all the beds at Saltwells between F^f and the conglomerate at the base of the Coal-measures as being Old Red Sandstone.

4. *The Old Red Sandstone.*—The Brewins Tunnel section continues at the same dip and regular bedding as the Temeside Shales, thus:—

	ft.	in.
Purple marls with thin (2 in.) bands of micaceous purple sandstones	12	0
Hard purple sandstone	1	0
Rubbly bluish-green sandstone	3	0
Micaceous purple and bluish-green sandstone	4	0
Micaceous bluish-green fissile sandstone underlying a conglomerate at the base of the Coal-measures. We cannot find any recognizable fossils in these beds	2	0
	22	0

Underlying the Coal-measure conglomerate, dipping west, that crops out over 150 yards to the W.N.W. of the tunnel, there are purple and green marls and sandstones in which a few obscure fossils have been found by us. Mr. Lewis has located basaltic intrusions in these beds which pass up into the Coal-measure Series.

Some 25 yards east of Messrs. Doulton's engine-house is this upward sequence, dipping S.S.E. 33°–40°—

	ft.	in.
Yellowish-brown sandstones	3	0
Ochre and bluish-red marls or clunch with (fish?) scales and *Onchus*	3	6
Red beds, with decomposed basalt, underlying Coal-measure yellow grits	4	0
	10	6

Mr. C. F. E. Griffiths kindly supplied to Mr. King details and a specimen of a pebble-bed, largely composed of angular pieces of rock similar to the above bluish-red marls, that was found 190 feet below the Thick Coal, three-quarters of a mile to the S.S E. at Saltwells Colliery No. 24, resting on 6 feet of binds.

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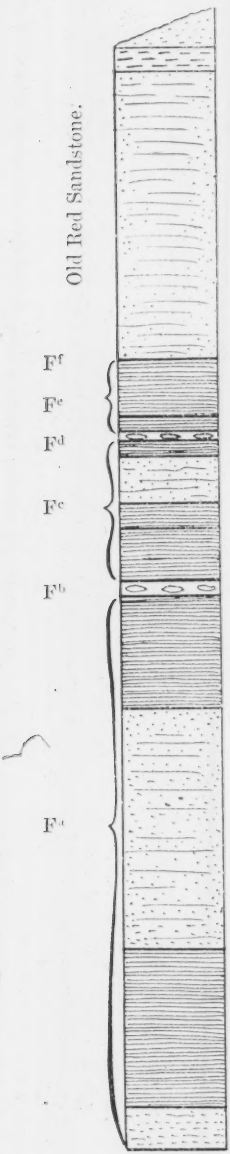

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The best sections of the Old Red Sandstones are in Black Brook, Saltwells Wood. Here the basal Coal-measure conglomerate can be seen resting directly on well-bedded purple, green, and brown micaceous sandstones interstratified in a thick mass of purple with some bands of light-blue marls. One band (south of the bridge) is a pebbly marl. Dr. A. Smith Woodward has kindly examined a few fossils found, and identifies a large specimen of *Onchus Murchisoni* (Agassiz) and fragments of various Ostracoderms. The dip is W.S.W. and west at angles varying from 50° to 16°, the steepest angles being on the western side of the strip. At the Leys Colliery, a quarter of a mile to the west, 261 feet below the Thick Coal, they pierced 25 ft. 8 in. of dark gritty rock and conglomerate, and then 3 feet of light-blue clunch and 60 feet of red clunch (marl).[1] The purple beds of Black Brook are nearly 200 feet thick. They clearly occupy a horizontal distance, at right angles to the strike, exceeding 300 feet; and then higher up the hill 400 feet to the east, at Lodge Farm, Downton Sandstones (E^c) with *Lingula minima* (common), *Modiolopsis complanata*, and *Beyrichia* sp. emerge also dipping west 35°. The brine bath well at Saltwells pierces the Old Red. The Saltwells Old Red compares favourably with this upwards sequence at Trimpley, near Kidderminster, 9 miles to the south-west, namely, (1) Temeside Bone-bed, 6 inches; (2) brown and yellow sandstones, 20 feet; (3) purple and green micaceous sandstones interstratified in a thick mass of purple marls.

Dr. W. Gibson, who has seen the Saltwells succession, points out that purple marls occur in the northern parts of the coal-field between the Millstone Grit and productive Coal-measures. He, however, agrees that it is improbable that the Black Brook purple beds are other than Old Red Sandstone, for they underlie a Coal-measure conglomerate which, according to our mapping, is the same as that at Brewin's Tunnel. Furthermore, within the coal-field the Carboniferous beds die out one after the other as they are followed southward, rendering it more likely that at Saltwells the Lower Carboniferous was removed by inter-Carboniferous denudation, as to which we give some facts below.

5. *The Base of the Carboniferous System.*—In the Saltwells Clay-pits the entire sequence from above the Thick Coal to the base of the Coal-measures is exposed. From the bottom of the Thick Coal to the base of the Coal-measures is 190 feet. The lowest of these rocks is a conglomerate 0 to 6 feet thick, passing upwards into yellow grits. The conglomerate varies in thickness, and in places dies out entirely. At Brewins Tunnel there are 28 feet of these grits and the conglomerate in the aggregate. The laminations are oblique. The largest pebble found at Saltwells is 14 by 10½ by 7 inches. At Saltwells these beds rest, in various sections, on different parts of the beds we include in the Old Red Sandstone, but in every section the dip agrees with the underlying rocks.

At the Hayes, Lye, one can see the conglomerate overstepping the

[1] *Silurian System*, 1839, p. 478. The lower part of the Carboniferous beds set out in this section crop out in Black Brook.

basset edges of, and then creeping up a small cliff composed of the Downton Sandstones. The strike of this little cliff is S.S.E. to N.N.W. A few yards away from the cliff the dip of the conglomerate and grits is 10° and of the underlying Downton Sandstones 30°. One immense pebble in the conglomerate is 36 by 18 by 18 inches. These observations confirm Mr. Jukes' views as to these deposits.[1] These basal rocks have been examined between the Lye on the south and Sedgley and Dudley on the north. The conglomerates are most persistent and coarsest to the south. The pebbles chiefly consist of quartzites, some of which are like the Cambrian quartzite that occurs in situ 5½ miles to the south-east of Lye at the Lickey. Pebbles of Llandovery Sandstone (*Pentamerus oblongus*), Silurian limestone, a clay ironstone nodule in which Dr. Arber has kindly identified *Neuropteris*, and pieces of coal also occur.

Comparison with the Ludlow District.

We wish to acknowledge the assistance that we have derived from Miss Elles' and Miss Slater's description of the uppermost Silurian of the Ludlow district, which is 28 miles W.S.W. of Saltwells.[2]

Their classifications, to a large extent, can be applied to South Staffordshire, but if one attempts, in the latter area, to adhere too closely to their palæontological zones, then difficulties arise, for certain fossils reach higher horizons in South Staffordshire than those recorded in Shropshire.

Mr. King examined the sections between Bow Bridge and the Mill Race, Downton, after we had nearly completed our work, and had previously examined the Whitcliff sections.

The Aymestry and Upper Ludlow groups are in the Ludlow district between 375 and 680 feet thick, whilst in South Staffordshire they are, say, 70 feet. The Upper Ludlow is 80 feet thick in the Tortworth district.[3] The flags and shales in B and C that are so thick at Ludlow are extremely thin in South Staffordshire, for A, B, and C form practically one band of limestone with only very thin partings.

Zone A of *Conchidium Knightii* can be determined. Above this zone our investigations, so far, only permit us to draw a line about 15–20 feet above the top of A, where we find the limestones are disappearing, and the bulk of the rock is calcareous sandstones in which *Chonetes minima* and *striatella* are very common. From this point to the Ludlow Bone-bed we treat as D. Between Zones A and D there is a zone where *Dayia navicula* is common, as at Ludlow. *Rhynchonella nucula* is, in the limestone bands, very abundant up to D^b, and is of no utility in South Staffordshire for determining a zone. D, though very much thinner than at Ludlow, does not differ to any very marked extent, except that we cannot fix by *Spirifera elevata* a zone D^b, that *R. nucula* and *O. elegantula* clearly ascend to D^c and perhaps still higher, and that *L. lata*, which at Ludlow occurs in B,

[1] *South Staffs Coalfields*, 2nd ed., p. 80.
[2] Q.J.G.S., vol. lxii, p. 195, 1896.
[3] Jukes-Browne's *Historical Geology*, 1st ed., p. 121.

ascends into D. *L. lata* at Saltwells is within 17 feet of D^c, and at Sedgley in the lower parts of D.

The Downton Castle Sandstones (E) at Forge Bridge, Downton, that are included in E^e, are thinly-bedded micaceous yellow sandstones. There are no such sandstones at Saltwells. Are they represented at Saltwells by the rusty-red marly sandstones at the top of E^d? At Saltwells E^d contains finer and more marly materials than E^d and E^e at Downton. Whilst *Platyschisma helicites* is very abundant at Downton Castle Bridge, we have to search carefully for a smaller species. *L. Lewisii*, which at Ludlow is rare in D^e, ascends abundantly in its smaller forms at Saltwells up to E^b. The Downton Sandstones at Saltwells are thicker, especially E^a and E^c. At both localities the massive yellow sandstones occur and have at their base the important *Platyschisma* shale.

The Saltwells Beds of Temeside age contain a quartzitic sandstone, and are more marly than those at Downton. Our Fig. 4 compares in thickness and zones very favourably with Miss Elles' and Miss Slater's figs. 6 and 7. But *L. minima*, rare at Ludlow in F^a, is common at Saltwells within a few inches of F^b. It is significant that the two bone-beds, F^b and F^d, and the two grit bands above are much more calcareous than any Mr. King could find in the Temeside Beds of the Downton district. Mr. Lewis finds that the composition of both F^b and ^{d} varies in the different samples of the same layer. Their average composition is approximately 36 per cent of sand and clay and 64 per cent of calcium carbonate.

The Igneous Rocks.

Mr. Lewis has examined the igneous rocks. They contain olivine (fresh), augite, often highly decomposed into chloritic products, felspar, intermediate between labradorite and andesine, and small quantities of magnetite. The felspar is centrally kaolinized, and the rock is traversed by calcite of secondary origin. The magnetite crystals show their crystal outline, and the felspars in rectangular sections are embedded in plates of augite. The rock is entirely free of glassy material, the residual magma having given rise to a second generation of felspars and augite. The rock is therefore an ophitic olivine dolerite.

In the field all the forms of basaltic jointing are shown, the most prominent being the spheroidal, with spheroids ranging up to a foot in diameter. The line of junction between the aqueous and the igneous rocks is distinctly marked. Fossils can be found at the junction, so contact metamorphism is very limited.

The dolerite is confined to the core of the anticline, and on both sides of the axis of the fold it tapers off in sills, some of which run into the Coal-measures. The dolerite appears as the crown of a laccolite sending out tongues into the sedimentary series.

There is an intimate relation between the faulting and the intrusions. At Brewins Tunnel the dolerite can be seen following the fault plane, and the microscope reveals incorporated fragments of sand grains which form part of the fault rock. The intrusion is therefore later than the formation of the W.S.W. to E.N.E. faults.

Movement along these fault planes may have taken place at widely different times, but we cannot find a section which would enable us to determine how far the basalt has partaken in the later movements.

Our investigations have resulted in these discoveries in South Staffordshire and North Worcestershire.

The Aymestry and Upper Ludlow groups are about 70 feet thick, as compared with 375 to 680 feet in the Ludlow district.

The following measures occur which have not hitherto been found at the surface :—

		Feet.
	Lower Old Red Sandstone, about	200
F.	Temeside Shales and Bone-beds	33
E.	Downton Castle or Yellow Sandstones with the *Platyschisma* shale	80
D^c.	The Ludlow Bone-bed. Not over	2
		315

Taken as a whole, without going into minute details, there are many similarities between the uppermost Silurian of Ludlow and South Staffordshire. In both areas the *Conchidium* limestone, *Chonetes* flags with the Ludlow Bone-bed, Downton Sandstone with its associated *Platyschisma* shale, and Temeside Shales and Bone-beds occur all in their regular order; and although some horizons do vary lithologically and palæontologically, yet these variations are such as might be accounted for on the assumption that in South Staffordshire and North Worcestershire the waters were throughout the period deeper and clearer, resulting in thinner, finer, and more marly and calcareous sediments being deposited, and in certain fossils, especially the different species of *Lingulæ*, surviving to higher horizons.

We heartily thank Mr. Willetts and other officers of the Birmingham Canal and Messrs. Doulton & Co. for the facilities they have granted to us in connexion with our investigations, and also Mr. Coulson, Principal of the Dudley Technical School, for the use of the chemical laboratory.

III.—The supposed Cretaceo-Tertiary Succession of New Zealand.

By Professor James Park, F.G.S.

THE theory of a Cretaceo-Tertiary succession in New Zealand was first formulated by Captain Hutton in the early seventies mainly on the evidence of the Waipara sections in North Canterbury, where there appeared to be an unbroken succession from the Cretaceous into the Lower Tertiary. He correlated the Weka Pass Stone with the Ototara Stone, and in the main his views were adopted by Sir James Hector and the Geological Survey.

Further investigation showed that the Ototara Stone in its typical localities in North Otago and South Canterbury was conformably underlain by a great succession of marine and terrestrial Lower Tertiary strata, while in North Canterbury the Weka Pass Stone was underlain by a great succession of Cretaceous strata. Obviously the Cretaceous strata could not be the time equivalent of the Tertiary

strata. Captain Hutton, who still correlated the Weka Pass Stone with the Ototara Stone, soon abandoned the Cretaceo Tertiary succession and introduced an unconformity between the Weka Pass Stone and the underlying Amuri Limestone, the hiatus representing as he believed the series of Tertiary strata which underlies the Ototara Stone in South Canterbury and North Otago.

If the Weka Pass Stone is the horizontal equivalent of the Ototara Stone, it is obvious that Captain Hutton's contention was unassailable. The position will be easily understood by a reference to Fig. 1.

The Tertiary beds *b*, *c*, *d*, varying from 400 to 1,000 feet thick, are absent in the North Canterbury sections.

After my first examination of the Waipara sections in the eighties I became an ardent supporter of the Cretaceo-Tertiary succession; but a wider knowledge of our younger rocks gained in later years convinced me that the position was untenable, and like Captain Hutton, its originator, I was reluctantly compelled to abandon it.

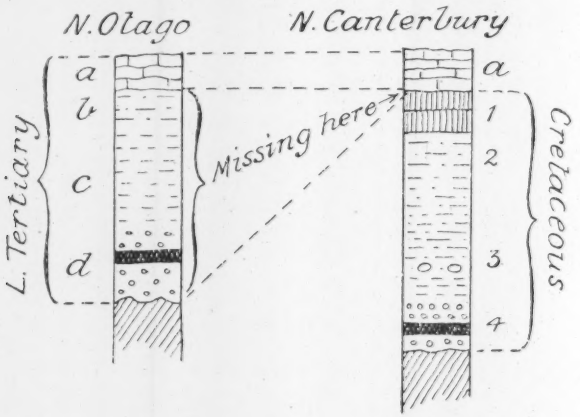


FIG. 1. *Tertiary:* (*a*) Ototara Stone; (*b*) glauconitic sands; (*c*) marly clays and sands; (*d*) quartzose sands with fireclays and brown coal.
Cretaceous: (1) Amuri Limestone; (2) glauconitic sands; (3) shaly clays with septarian concretions containing Saurian remains; (4) quartzose sands with shales and brown coal.

After a lapse of nearly a quarter of a century Dr. Marshall and his colleagues view the Waipara sections, and, influenced by the apparent conformity of the Tertiary and Cretaceous strata, become enthusiastic advocates of the Cretaceo-Tertiary succession. The contentions I used in favour of the succession are now quoted against me. Of this I do not complain. I did the same with Captain Hutton. To the young geologist there is always something attractive and alluring about a Cretaceo-Eocene succession, and I have no doubt that its recrudescence will be periodic with every new generation of geologists.

Dr. Marshall recognizes that the Ototara Stone is conformably underlain by a great succession of marine beds containing a Tertiary fauna, and the Weka Pass Stone by a Cretaceous fauna. This leads him to revive the theory of overlap, which was frequently discussed

in the old Geological Survey days, but found to be untenable, since at places as distant as North Auckland and as far south as South Otago both the Lower Tertiary and Cretaceous faunas are found in juxtaposition.

At Wade, north of Auckland, the Waitemata Beds rest highly unconformably on the Cretaceous strata. Dr. Marshall is in error in saying that this section was not described when first discovered.[1] The actual junction of the Tertiary Waitemata and the Cretaceous beds is beautifully exposed in a vertical sea-cliff, and the figure which accompanied my report is reproduced below.

The septarian beds everywhere in the North Auckland district underlie the hydraulic (Amuri) limestone, notably at Wade, Mahurangi, Hikurangi, Kawa-Kawa, and Batley, opposite Komiti Point. Moreover, as reported at the time, I discovered blocks of hydraulic limestone in the Lower Waitematas near Howick and Onehunga.

No geologist has ever doubted the Oamaruian age of the Waitematas; and the hydraulic limestone is a member of the Cretaceous coal formation, as proved by boreholes at Kawa-Kawa.[2]

At Shag Point in Otago, as described by me in the December, 1911, issue of the GEOLOGICAL MAGAZINE,[3] the Cretaceous strata

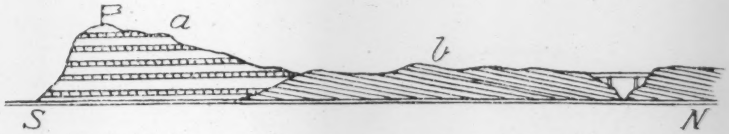


FIG. 2. Section Orewa Bridge to South Head. (*a*) Thin-bedded Tertiary sandstones and clays; (*b*) sandy clays with septaria.

form the north wall of the Shag Valley. They are sharply tilted and folded, and rest on the Palæozoic mica-schists. The floor of the valley is occupied by horizontal or gently dipping Lower Tertiary strata, typically Oamaruian, which, as so clearly brought out by Mr. A. Gordon Macdonald in his carefully contoured geological maps of this area, abut against the Cretaceous Series from the head of the valley to the sea, and going southward rest on the mica-schists.

Professor Cox and Mr. A. McKay believed that a fault existed along the north side of the Shag Valley, and this view fitted in quite consistently with the old view of the Geological Survey that the Tertiary beds in the floor of the valley were the horizontal equivalents of the Cretaceous Shag Point Beds. But Dr. Marshall rightly enough recognizes that the Tertiary beds cannot be the time equivalents of the Cretaceous Shag Point Beds, and contends that the Tertiary beds follow the Shag Point Beds conformably, but have been faulted down to the floor of the valley. The supposed fault was the natural

[1] Geol. Reports and Explorations, 1886–7, p. 226.

[2] A. McKay, Geol. Reports and Explorations, 1883, p. 133.

[3] J. Park, "The Unconformable Relationship of the Lower Tertiaries and Upper Cretaceous of New Zealand": GEOL. MAG., Dec. V, Vol. VIII, No. 570, pp. 539–49.

corollary of the view of the old Survey, but is entirely opposed to that of Dr. Marshall, for obviously if the Tertiary beds follow the Cretaceous conformably they should rest, not on the basement mica-schists, but on that portion of the Cretaceous from which they are supposed to have been dissevered.

Dr. Marshall,[1] when discussing the Shag Point section, lays much stress on the circumstance that the actual contact of the horizontal Tertiaries and uptilted Cretaceous is obscured by recent detritus. He infers all kinds of geological possibilities between the junction, but

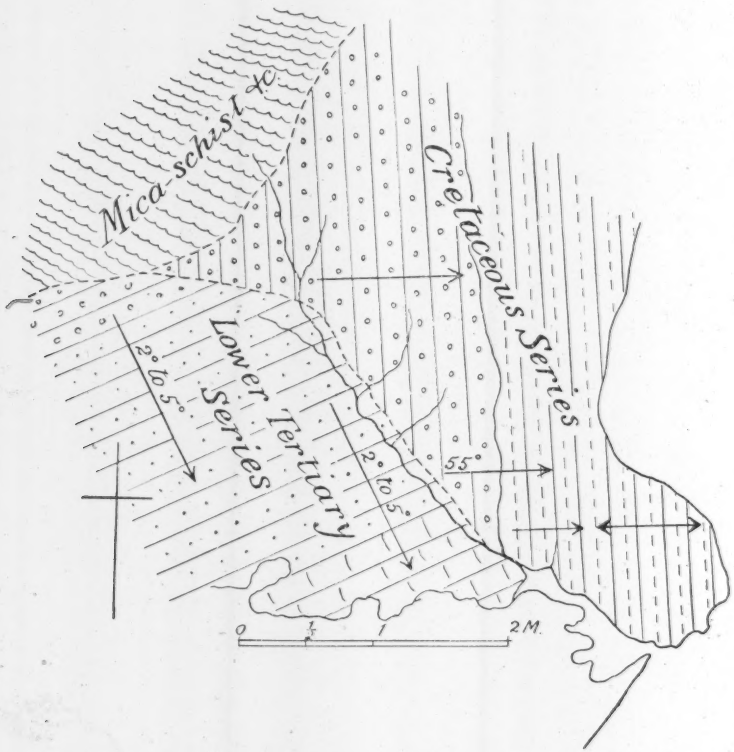


FIG. 3. *Tertiary Series:* (*a*) Calcareous sandstone; (*b*) glauconitic sandstone; (*c*) blue clays and soft sandstones; (*d*) quartzose conglomerate with brown coal; (*e*) mica-schist.

Cretaceous Series: (1) Greensands and shaly clays with septarian concretions; (2) gritty sandstones; (3) quartz sands and conglomerates with brown coal; (4) quartzose conglomerates passing into quartzose and mica-schist breccia.

nevertheless invokes the aid of a fault running along the junction, seemingly failing to recognize that the effect of the fault would be to make the two formations abut against one another. Such veteran

[1] GEOL. MAG., July, 1912, p. 318.

geologists as Sir James Hector, Mr. Alexander McKay, Sir Julius von Haast, and Professor Cox had no misgivings on this point when mapping the Shag Point district.

In his reference to the Kaitangata district in South Otago Dr. Marshall[1] says that since no actual contact of the Lower Tertiary and Cretaceous formations are seen, "obviously this unconformity is a matter of inference." But the unconformity cannot be so lightly disposed of as this. When dealing with the Shag Point section he has also, as we have seen, laid great stress on this contention that there is no visible contact. He fails to realize (*a*) that visible contacts between different formations are not the rule, but the exception; and (*b*) that a field-geologist has no difficulty in delineating the distribution of two formations that are petrographically and palæontologically different, more especially when the general arrangement of the strata comprising the formations lends its powerful assistance. The Kaitangata and Tertiary coal-bearing formations differ as widely as the proverbial chalk and cheese, as may be seen by a perusal of the following tabulated statement:—

Tertiary Formation.	Kaitangata (Cretaceous) Series.
(*a*) Limestone (glauconitic).	(*a*) Compact sandstones and shales.
(*b*) Hard limestone.	(*b*) Hard greywacke conglomerates with numerous seams of superior bright-brown coal.
(*c*) Glauconitic sands.	(*c*) Brown sandstones with calcareous horizon containing marine shells.
(*d*) Quartzose sands and conglomerate with lignite seam.	(*d*) Thick bands of quartzose conglomerate and quartzose sands with seam of lignite.

The Kaitangata Series, which is bent into folds, rests directly on a highly eroded surface of the altered greywacke and slaty shales of the Kakanuian (Older Palæozoic) and mica-schists of the Maniototian; while the Tertiary Series, which is horizontal, lies in some places on the Kakanuian, in others wraps round the boundaries of the Kaitangata Beds in a way that clearly indicates unconformity, notwithstanding that the actual junction is obscured by glacial drifts and clays.

The Cretaceous Series contains two coal horizons, namely, a lower consisting of quartzose conglomerates and sands with one seam of lignite, and an upper consisting of massive bands of greywacke conglomerate containing many seams of hard bright coal.

The Tertiary beds contain a rich fauna that is distinctively Oamaruian. The Kaitangata marine horizon, which lies between the two terrestrial stages, contains *Conchothyra parasitica*, a peculiarly distinctive Cretaceous form, a new *Turritella* (*T. semiconcava*), *Belemnites lindsayi*, and a rich assemblage of undescribed mollusca that possess a facies resembling the fauna underlying the hydraulic (Amuri) limestone and overlying the coal at Kawa-Kawa in North Auckland. The point at issue is not so much one of conformity or unconformity as the more immediate one that if the overlap hypothesis be true the Cretaceous fauna ought not to exist in Otago.

[1] Geol. Mag., July, 1912, p. 318.

At New Brighton, near Dunedin, there is a remnant of the Cretaceous Series consisting of an impure rubbly sandy limestone underlain by loose quartzose sands and interbedded with fireclays and a seam of lignite. The marine bed contains many broken unrecognizable shells and a true Belemnite (*B. lindsayi*). The Cretaceous beds rest directly on the mica-schist, and are overlain by the dirty greenish-coloured soft micaceous sandstones of the neighbouring Tertiary coal series of Saddle Hill and Green Island, the complete succession of which is as follows, reading downwards :—

(*a*) Caversham sandstone (Ototara Stone).
(*b*) Glauconitic sands.
(*c*) Blue marine clays.
(*d*) Dirty green micaceous sandstones.
(*e*) Quartzose sands with a seam of lignite near the base.

In an interesting paper on the geology of the Lower Waipara Gorge[1] Mr. R Speight, one of Dr. Marshall's colleagues, describes the occurrence of a Tertiary fauna in the beds overlying the grey marls containing more than 30 per cent of living species. According to recognized standards the age of these beds should be, as he says, an Upper Miocene or Lower Pliocene. The grey marls consist of a horizon of sandy clays lying between the Weka Pass Stone and the Mount Donald Beds. Below the Weka Pass Stone we have only a Cretaceous fauna. Does not this biological discordance suggest a marked palæontological unconformity ? The stratigraphical conformity is only apparent ; the palæontological break is pronounced. Mr. Speight, while still adhering to the stratigraphical conformity of the Tertiary and Cretaceous Series, concludes with the significant remark : "This statement [*in re* conformity] does not, however, negative the existence of a palæontological break."

The calcareous beds which form the higher members of the Oamaru system are dominated by Brachiopods, Pectens, Echinoderms, Corals, and Foraminifera, only a few of which are represented by living species, while the underlying marine clays and sandy beds contain a rich fauna of Lamellibranchs and Gasteropods, of which, as found at Hampden, Ngapara, Black Point, Wharekuri, Waihao, Waipara, and Weka Pass, from 25 to 30 per cent are living species. Of the few species which range throughout the whole of the marine stages of the Oamaruian are *Pseudamusium huttoni* (Park) and *Cirsotrema browni* (Zittel). These two beautiful species are scarce in the blue sandy beds in which they first make their appearance, attain their maximum development in the glauconitic sands, and make their last appearance in the Ototara Stone, in which they are nowhere abundant. Their discovery in the Weka Pass Stone in the Waipara district as reported by Dr. Thomson and Mr. Cotton cannot be regarded as proving that the Weka Pass Stone is the time equivalent of the Ototara Stone. What it does prove is that Captain Hutton was right in placing the unconformity between the Oamaru and Waipara systems at the close of the Amuri Limestone. Moreover, the shattered and undulating

[1] R. Speight, "A Preliminary Account of the Lower Waipara Gorge" : Trans. N.Z. Inst., vol. xliv, pp. 221–33, 1911.

surface of the Amuri Limestone which I critically examined last March for the first time seems to be corroborative of Hutton's view. The discordance is as well marked as that between the Cretaceous and Eocene of South England.

Dr. Marshall, by insisting that the absence of a marked physical break at Waipara between the Tertiary and Cretaceous strata is an evidence of a Cretaceo-Tertiary succession, seems to have overlooked the fact that the physical unconformity between the Cretaceous and Eocene in England is so slight that it is not visible in single sections, and is only capable of proof on palæontological grounds. Furthermore, in England the Eocene nowhere extends beyond the Chalk outcrop, thereby showing a closer physical relationship between these formations than exists in New Zealand, where the Lower Tertiary strata rest in most places on formations older than the Cretaceous.

It is worthy of note that the places where the Lower Tertiary system of New Zealand rests on the Cretaceous are few and widely separated. In most places the Tertiaries rest on older rocks. This widespread overlap beyond the Cretaceous outcrop is in itself significant. It is obvious that when the subsidence which ushered in the Tertiary took place, the first areas to be invaded by the Eocene seas would be the Cretaceous basins. The remarkable overlap beyond the Cretaceous outcrop seen throughout New Zealand may be therefore taken as an evidence of widespread and prolonged, if not rapid, subsidence at the close of the Cretaceous; while the large proportion of living species in the lowest marine beds of the Tertiary system may not unreasonably be held to mark a wider gap than that between the Cretaceous and Lower Tertiary of England.

Dr. Marshall's correlation of the Hutchinson Quarry Beds with the Weka Pass Stone is entirely at variance with the palæontological evidence. The Hutchinson Quarry Beds are intimately related to the Oamaru Stone, and contain a rich and distinctive fauna of Brachiopods, Pectens, Corals, and Bryozoans, that led Sir James Hector, Sir Julius von Haast, Captain Hutton, Professor Cox, and Mr. Alexander McKay without hesitation to correlate them with the Mount Brown or Mount Donald Beds, which lie 300 or 400 feet above the Weka Pass Stone in the typical sections in North Canterbury. All the palæontological evidence that has accumulated during the past twenty-five years has merely served to confirm the soundness of their correlation.

The Hutchinson Quarry Beds, consisting of glauconitic sands, tuffs, and limestones, together with the closely associated Oamaru Stone, are in my opinion the equivalents of the Kakanui Limestones = Ototara Stone = Waitaki Stone = Waikao Stone = Mount Somers Stone = Mount Brown and Mount Donald Stones in North Canterbury.

A critical review of the evidence seems to establish the view that we have two coal-bearing formations in New Zealand, as so long maintained by Captain Hutton, namely, the Waipara System, of Cretaceous age, and the Oamaru System, of Lower Tertiary age. Each formation begins with terrestrial beds containing seams of coal and closes with a calcareous marine horizon. The Cretaceous System rests on older Secondary and Palæozoic rocks, the Oamaruian on the

Cretaceous and older formations. In the Waipara district, where the terrestrial beds of the Oamaruian are absent, the physical break between the Cretaceous and Tertiary is not well marked, but the palæontological break is complete. In all other parts of New Zealand wherever the terrestrial beds of the Oamaruian are present, the stratigraphical break between the Cretaceous and Tertiary is as conspicuous as the palæontological.

IV.—The Chemical Examination of the Carboniferous Limestones of the Avon Gorge.

By Mildred B. Chapman, B.Sc., D.I.C.

In view of the attention which has been drawn of recent years to the mode of origin of the purer limestones, I have been led to prosecute some inquiries under this head on the Carboniferous Limestones of the Avon Gorge, near Bristol. I have paid greatest attention to the chemical composition of the rocks, particularly the proportion of insoluble residue remaining after treatment with hydrochloric acid; at the same time I have not wholly neglected the fossil contents, although for information on this point I have mainly relied on other observers.

The method of analysis which I adopted was similar to that used by Professor Skeats in his investigations on the Dolomites of the Tyrol, so that the results can easily be compared. Briefly it was as follows:—

The finely powdered limestone, after solution in strong hydrochloric acid and evaporation to dryness, was again moistened with the acid and evaporated. The mass was lixiviated with water containing a few drops of hydrochloric acid and the weight of residue determined. This residue was examined under the microscope, but I have not attempted to give a detailed description, as this has already been done by Mr. E. Wethered (Q.J.G.S., 1888). Iron and aluminium hydroxides were precipitated from the solution by means of ammonia, and the content of iron oxide and alumina determined as a whole.

The percentage of lime was ascertained by titration with potassium permanganate after precipitation by means of ammonium oxalate. Magnesia was weighed as magnesium pyrophosphate, obtained by precipitation with sodium phosphate and ammonia.

A separate estimation was made of the carbon dioxide in the usual manner, using soda lime for absorption.

Each specimen was also carefully tested for the presence of phosphoric acid.

Except when otherwise stated the figures given are the average of several analyses.

Sections of the same specimens of the rocks were examined microscopically and were treated with Lemberg's solution to distinguish the dolomite if present.

Specimens were collected throughout the Avon Gorge section except from the shale and argillaceous bands, which were neglected, as they do not come within the scope of this paper. Special care was taken to obtain samples from all marked coral bands.

The classification of the beds is that laid down by Dr. Vaughan (Q.J.G.S., 1905).

Tournaisian.

a. *Modiola Phase.*—The passage beds between the Old Red Sandstone and Carboniferous Limestone.

Ca O	44·34
Mg O	5·23
$C O_2$	43·51
$Fe_2O_3 + Al_2O_3$	1·98
Insoluble residue	5·22
Total	100·28

The insoluble residue in various specimens of this zone varies between 3·24 per cent and 11·18 per cent, and consists chiefly of quartz flakes and rounded detrital quartz, felspar (much weathered), and carbonaceous material, mainly bitumen. A few microscopic crystals of zircon, some sponge spicules, and casts of crinoid ossicles preserved in chalcedony are also present. The proportion of insoluble residue is unusually large, as is to be expected in view of the probable proximity of slowly sinking Old Red Sandstone land areas.

No corals have yet been recorded from these beds, and it thus appears that they do not represent coral reefs.

K. Cleistopora Zone.

K_1. *Productus bassus* subzone.

	A.	B.
Ca O	45·83	48·21
Mg O	6·53	2·16
$C O_2$	43·26	44·72
$Fe_2O_3 + Al_2O_3$	·94	·43
Insoluble residue	3·71	4·53
Total	100·27	100·05

The insoluble residue content varied from 2·41 to 4·53 per cent. Analysis A shows the average composition and B that of the specimen having the greatest proportion of insoluble residue.

The residue consists of well-rounded detrital quartz, chalcedonic silica, small zircons, much kaolinized felspar, and some tourmaline.

K_2. *Spiriferina octoplicata* subzone.

	A.	B.	C.
Ca O	50·93	49·44	51·04
Mg O	6·07	7·42	6·28
$C O_2$	42·70	43·54	42·42
$Fe_2O_3 + Al_2O_3$	·42	·38	·45
Insoluble residue	·21	·19	·07
Total	100·33	100·97	100·26

A, B, and C give the analyses of the lower, middle, and upper portions of this subzone respectively.

The percentage of insoluble residue varies between ·07 and ·21, and is therefore very low.

Corals are rare throughout the subzone, occurring most abundantly at the top. Brachiopods are plentiful, especially *Spiriferina octoplicata*. This cannot be a coral reef from which the coral

structure has since disappeared, as the Brachiopods and some Corals still remain without the loss of their structure.

It is therefore a chemically pure limestone which nowhere exhibits the structure of a coral reef.

β. Passage beds between K and Z zones.

Ca O	41·99
Mg O	9·99
CO_2	42·53
$Fe_2O_3 + Al_2O_3$	·63
Insoluble residue	4·95
Total	100·09

The insoluble residue consists chiefly of detrital quartz and black carbonaceous material. Analyses of different parts of these beds gave very constant results, the amount of insoluble residue only varying between 4·78 per cent and 4·96 per cent.

Z. Zaphrentis Zone.

Z_1. *Spirifer clathrata* subzone.

	A.	B.
Ca O	46·34	32·95
Mg O	2·17	16·76
CO_2	36·30	39·74
$Fe_2O_3 + Al_2O_3$	·61	·29
Insoluble residue	14·51	10·34
Total	99·93	100·08

A and B are analyses of those specimens which have the greatest and least amount of insoluble residue. This residue consists of detrital quartz, quartz with secondary deposition of silica, small zircons, and some pyrites; most of the material was much rounded, as if by current action or under littoral conditions.

Z_2. *Zaphrentis koninckı* subzone.

Ca O	55·63
Mg O	1·73
CO_2	42·22
$Fe_2O_3 + Al_2O_3$	·29
Insoluble residue	·43
Total	100·30

The percentage of insoluble residue varies from ·37 to ·46—most of this is silica; secondary deposition has often formed perfect doubly terminated crystals. Minute zircons, fragments of tourmaline, some carbonaceous material, and small quartz flakes also occur.

Marked coral bands occur throughout this subzone.

γ. Passage beds between zones Z and C.

Ca O	41·99
Mg O	10·68
CO_2	41·43
$Fe_2O_3 + Al_2O_3$	·93
Insoluble residue	4·95
Total	99·98

The insoluble residue resembles that of the Z_2 subzone.

These beds are approximately contemporaneous with the igneous rocks of the Weston-super-Mare district, and the proximity of this area, combined with current action, may account for the great variation in the amount of insoluble residue between the base of the Z and the beginning of the C zone.

C. Caninia Zone.

C_1. (1) *Laminosa* Dolomite; (2) *Caninia* Oolite.

C_2. (3) *Caninia* Dolomite.

	(1)	(2)	(3)
Ca O	45·19	55·58	42·98
Mg O	10·32	—	10·94
$C O_2$	43·62	44·22	42·04
$Fe_2 O_3 + Al_2 O_3$	·38	·15	·49
Insoluble residue	·75	·05	3·48
$P_2 O_5$	trace	·14	·12
Total	100·26	100·14	100·05

The percentage of insoluble residue is low, being never greater than 3·48 per cent and usually below 1 per cent. In view of the proximity of igneous action the low percentage of insoluble residue is remarkable.

The residue consists of black carbonaceous material with some bitumen, greyish devitrified glass, brown-stained quartz grains, some minute flakes of quartz, and chalcedonic silica. These beds contain an appreciable amount of phosphate, probably calcium phosphate.

Viséan.

S. Seminula Zone.

S_1. *Productus* aff. *semireticulatus* subzone.

	A.	B.
Ca O	46·34	48·21
Mg O	2·07	·84
$C O_2$	36·39	37·93
$Fe_2 O_3 + Al_2 O_3$	·58	5·87
Insoluble residue	14·50	7·41
Total	99·88	100·26

Analyses A and B correspond to the specimens having the greatest and least percentage of insoluble residue. The high percentage may be due to igneous activity in the adjacent district of North Somerset, but the direction of the prevailing currents would have to be materially different from that of the period during which the immediately preceding rocks were deposited, as they contain a very small amount of insoluble residue. No diminution in the percentage of insoluble residue was detected in the marked coral bands.

The residue consists of well-rounded detrital quartz, often brown-stained, bitumen, other fine carbonaceous material, and siliceous sponge spicules. Quartz flakes occur in the upper part.

S_2. *Productus cora*, mut. S_2 subzone.
Seminula Oolite.

Ca O	54·82
Mg O	·68
$C O_2$	44·16
$Fe_2 O_3 + Al_2 O_3$	·12
$P_2 O_5$	·12
Insoluble residue	·26
Total	100·16

As is usual in the Oolitic limestones there is very little impurity. The Mg O cannot be seen as dolomite rhombs in thin sections of the rock even when treated with Lemberg's solution, and can only be detected on analysis.

The insoluble residue consists of fine argillaceous material, quartz with secondary growth, zircons, pyrites, and well-developed siliceous sponge spicules. No carbonaceous material is present.

No coral bands occur, so the small amount of insoluble residue cannot be due to the formation of these beds under coral-reef conditions.

D. Dibunophyllum Zone.

D_1. *Dibunophyllum* θ subzone.

	Base.	Middle.	Top.
Ca O	49·50	55·60	29·38
Mg O	5·92	—	·82
$C O_2$	41·96	44·05	24·62
$Fe_2 O_3 + Al_2 O_3$	·21	·08	2·15
Insoluble residue	2·51	·45	43·29
Total	100·10	100·18	100·26

The insoluble residue is mainly rounded detrital silica and quartz flakes. Much carbonaceous material occurs at the top, bitumen in one case constituting 4·16 per cent of the entire rock.

D_2. *Lonsdalia floriformis* subzone.

Ca O	54·96
Mg O	—
$C O_2$	43·41
$Fe_2 O_3 + Al_2 O_3$	·66
Insoluble residue	1·84
Total	100·87

The content of insoluble material varies between ·02 and 2·41 per cent—it is chiefly quartz and fine argillaceous material. The *Dibunophyllum* zone contains many marked coral bands, and was probably deposited under "coral-reef conditions". It contains a very variable amount of insoluble residue up to as much as 43·29 per cent.

On examining the foregoing results it will be seen that the beds which have been formed under coral-reef conditions have a very variable amount of insoluble residue.

In the rocks analysed it varies between ·43 in Z_2 and 43·29 in D_1. On the other hand, rocks which do not appear to have been formed under coral-reef conditions, e.g. K_2, are remarkably pure. On the

whole the lowest proportion of insoluble residue was obtained from the Brachiopod limestones and the Oolitic bands.

My examination therefore confirms the view expressed by Professor Skeats ("Dolomites of the Southern Tyrol," Q.J.G.S., 1905), viz., that chemically pure limestones are formed by rapid deposition near a coastline which is usually composed of calcareous rocks, from the waste of which the material is obtained.

On the other hand, I have obtained no evidence that such limestones are formed necessarily under coral-reef conditions, but rather that such conditions are by no means essential, and that the amount of insoluble residue depends on the action of the currents.

The analyses in this paper were carried out in the Geological Laboratories of the Imperial College of Science and Technology, and I wish to express my gratitude for much kind advice and assistance to Professor W. W. Watts and other members of the staff of the College.

V.—Cambrian Geography.

By A. J. Jukes-Browne, F.R.S., F.G.S.

PROFESSOR PEACH'S address, as President of Section C at the recent meeting of the British Association, concludes with some interesting remarks on the geographical conditions of Cambrian time, and these may be regarded as an amplification of the views which he had previously expressed to the Royal Society of Edinburgh (1886) and in the Geological Survey memoir on the *Structure of the N.W. Highlands of Scotland* (1907).

I had occasion to comment on these views in the recent edition of my *Building of the British Isles* (1911), and am glad to find I correctly interpreted his original suggestion as meaning that a sea with continuous shore-lines stretched across the Atlantic region from Canada to Ireland, and that this sea separated two different zoological provinces of littoral Invertebrata.

In this general statement there is now a complete agreement between us, because, as he says, it seems a reasonable inference from the palæontological evidence, but it is not so easy to follow the arguments by which he endeavours to support the more detailed exposition of his hypothesis.

He begins by assuming that the materials of the Torridon Sandstone and of the newer Algonkian rocks of Canada were derived from a land which formed a continuous belt from Scandinavia to North America. He continues: "During the period which elapsed between the deposition of the Torridon Sandstone and the basement members of the Cambrian system a geosyncline was established which gave rise to a submarine trough, trending in an E.N.E. and W.S.W. direction both in the British and North American areas. In the latter region it extends from Newfoundland to Alabama, its south-eastern limit being defined by the old land surface of Appalachia. The extension of this Appalachian land area in a north-east direction, beyond the limits of Nova Scotia and Newfoundland, was postulated by Dana and other American writers."

It will be seen that the statements in this passage are not consistent with one another. A trough which passed across the Atlantic from Scotland to Newfoundland would, if prolonged, extend to Iowa and not in the direction of Alabama. The line from Alabama to Newfoundland is very nearly south-west to north-east, and if prolonged would pass through Iceland, but would not touch Scotland nor even the extreme north of Norway.

The Appalachian ranges and the Caledonian flexures are parallel to one another, not parts of a continuous ge-anticline. Moreover, they were formed at a much later date in the world's history, and there is no reason for supposing that they were in any sense initiated in Cambrian time, or that there was a corresponding geosyncline "which remained a line of weakness throughout Palæozoic time". I need hardly point out that parallel ge-anticlines, one in Europe and one in North America, would not form a connecting shore-line between the two regions.

The fact is that Professor Peach is only correct so far as the W.S.W. line from Scotland to Newfoundland is concerned, and there is no need for the introduction of a geosyncline of any kind. All that the facts warrant is the inference that there was a continuous coastline from Norway to Canada with open sea to the south of it. This coastline would have a general trend from E.N.E. to W.S.W., but may in many places have run nearly due east and west.

If this is granted the rest of Professor Peach's restoration becomes comprehensible and probable. Instead of the Cambrian rocks of the North-West Highlands being "laid down along the N.W. side" of a trough or geosyncline, they were really formed along the northern border of a North Atlantic sea, that is, on the southern side of an east and west tract of land extending from Norway to Greenland and Labrador.

Further, he now agrees with me that the Cambrian strata of Wales were deposited along the southern side of this sea, and he thinks that "this southern land area in Western Europe was continuous across the Atlantic with Appalachia". Presumably the northern shore of this land ran from Cornwall to Nova Scotia, crossing the Atlantic in a general east to west direction, more or less parallel to that of the northern land. It is of course a big assumption to bridge the Atlantic for more than 2,000 miles with continuous land, but, being myself convinced that Palæozoic lands and seas were entirely different both in position and in trend from those of the present day, I see nothing unlikely in the existence of such a land area during the Cambrian period.

I do, however, protest against the hypothesis of a single trough formed by a geosyncline and extending from Norway to Alabama, a distance of nearly 4,000 miles. There is really no evidence on which to base such a piece of imagination, nor can I see any necessary connexion between the geographical extension of the Cambrian sea and the subsequently formed Caledonian system of flexures. An oceanic area is not necessarily a geosyncline, and even the North Atlantic of the present day comprises two troughs separated by a median ridge.

Finally, it seems possible to form some idea of the width of the sea space between the opposing shores of the Atlantic and Arctic continents of Cambrian time. Supposing its average breadth on the European side was equal to the distance from lat. 50, which touches the south of Cornwall, to the Faroe Islands; this is about 850 miles, which is double the average width of the Mediterranean, and is consequently quite a sufficient distance for the development of a considerable depth of water.

Hence, it is very probable that the marine inhabitants of the northern shore of the Cambrian Atlantic Sea would be different from those of the southern shore, and that such a broad expanse of comparatively deep water would prevent migration from one side to the other, especially if a strong current swept along the northern side from west to east and a return current set in the opposite direction along the southern side. The American character of the Scottish Cambrian faunas will thus be satisfactorily explained.

VI.—Two New Species of Cirripedia from the Tithonian of Stramberg, Moravia.

By Thomas H. Withers, F.G.S.

(PLATE XXIII.)

DR. M. REMEŠ, of Olmütz, Bavaria, recently submitted to Dr. F. A. Bather for determination, a small suite of fossils collected by him from the Tithonian of Stramberg, Moravia. Among them were two Cirripede valves which Dr. Bather kindly handed to me for identification. These two carinal valves cannot be referred to any of the described species, and, since they differ much from each other in size and ornament, I have felt myself compelled to describe them as separate species. The specimens remain in the collection of Dr. M. Remeš, but reproductions are preserved in the Geological Department of the British Museum.

Systematic Position.—Although we have only two carinæ before us, it is possible, with some probability of correctness, to indicate their systematic position.

In the known species of *Archæolepas* the carina is very small, somewhat triangular in shape, and slightly expanded at the basal angles. The present carinæ, therefore, cannot with much confidence be referred to that genus.

It seems much more probable that they belong to the genus *Brachylepas*, rather than to *Pollicipes*. The genus *Brachylepas* was founded (1901)[1] to embrace a single species, *Pyrgoma cretacea*, H. Woodward (= *Brachylepas Naissanti*, Hébert, sp.),[2] from the Upper Senonian, but Dr. Woodward subsequently (1906)[3] referred to it the

[1] H. Woodward, "On '*Pyrgoma cretacea*', a Cirripede, from the Upper Chalk of Norwich and Margate": Geol. Mag., Dec. IV, Vol. VIII, p. 150, 1901.

[2] See T. H. Withers, "The Cirripede '*Brachylepas cretacea*', H. Woodward": Geol. Mag., Dec. V, Vol. IX, p. 321, 1912.

[3] H. Woodward, "Cirripedes from the Trimmingham Chalk and other localities in Norfolk": Geol. Mag., Dec. V, Vol. III, pp. 339–40, 1906.

species *Pollicipes lithotryoides*, Bosquet sp., from the Maestrichtian, and *P. fallax*, Darwin, from the Upper Senonian. With *B. fallax* in particular both the carinæ now to be described agree remarkably in general shape, structure, and type of ornament, so that, in the absence of more precise evidence as to the remaining valves, they may be referred provisionally to the genus *Brachylepas*.

Brachylepas (?) fimbriatus, sp. nov. Pl. XXIII, Figs. 1*a*, *b*.

Diagnosis.—Carina semi-cylindrical, strongly convex transversely, not carinated, with an almost straight basal margin. Ornamented exteriorly with about nineteen regularly-spaced, prominent, transverse ridges, extending almost straight across the valve, closely and regularly undulatory, having a goffered appearance, which is emphasized by the ridges being crossed by about eighteen rounded longitudinal ridges radiating from the apex; the growth-lines between the transverse ridges also form slightly-raised ridges.

Material.—A single well-preserved carina, somewhat broken at the apex, and embedded in a piece of hard red limestone.

Horizon and Locality.—Tithonian, Red Limestone: Stramberg, Moravia.

Description of Holotype.—Carina semi-cylindrical, widening gradually from the apex to the basal margin; slightly bowed inwards; strongly convex transversely, not carinated; basal margin almost straight, but in the earlier stages of growth there is a tendency for the transverse ridges to be convex near the margins and concave in the middle. Outer surface ornamented with about nineteen prominent transverse ridges, terminating each period of growth, and extending almost straight across the valve, the growth-lines between also forming slightly-raised ridges; these ridges are regularly and closely undulatory, and the main transverse ridges are steep-sided towards the basal margin, the steep sides being smooth. The transverse ridges are crossed by about eighteen rounded, longitudinal ridges, which are slightly less prominent than the main transverse ridges, and give to them a conspicuously goffered appearance. By the crossing of the transverse and longitudinal ridges the structure of the outer surface appears somewhat cancellated. Inner surface not exposed, but the apical portion probably projected freely to some extent.

Length of valve, *circa* 13 mm.; greatest breadth, 5·1 mm.

Brachylepas (?) tithonicus, sp. nov. Pl. XXIII, Figs. 2*a*, *b*.

Diagnosis.—Carina semi-cylindrical, strongly convex transversely, not carinated, with the basal margin slightly concave in the middle and convex at the sides. Ornamented exteriorly with several regularly-spaced, sharp-edged, transverse ridges, not undulatory, the sharp edges having a rather beaded ornament; the spaces between the transverse ridges are smooth.

Material.—A single large carina embedded in a piece of hard white limestone. The apex of the valve has been broken away, and the

remaining portion of the valve is somewhat fractured, but the outer surface is well-preserved.

Horizon and Locality.—Tithonian, White Limestone: Stramberg, Moravia.

Description of Holotype.—Carina semi-cylindrical, widening gradually from the apex to the basal margin; slightly bowed inwards; strongly convex transversely, somewhat flattened at the sides, not carinated, basal margin slightly convex at the sides and slightly concave in the middle, which is more pronounced in the earlier stages of growth. Outer surface ornamented with several (twenty-four on the portion preserved) prominent, sharp-edged, regularly-spaced, transverse ridges, terminating each period of growth, the spaces between being smooth; these transverse ridges are *not* undulatory, and their sharp edges have a somewhat beaded ornament, which may possibly be attributed to obsolescent longitudinal ridging (about sixty bead-like prominences can be counted on one near the middle of the valve). Inner surface not exposed, but the apical portion probably projected freely to some extent.

Length, *circa* 22·4 mm.; greatest breadth, 11·6 mm.

Comparison with other Species.—*B.* (?) *fimbriatus* agrees in general form with the carina described as *B.* (?) *tithonicus*, sp. nov., and both valves are evidently of the same type. *B.* (?) *tithonicus* differs greatly in size, being more than twice the length of *B.* (?) *fimbriatus*; it differs also in having rather more steeply inclined sides, in the absence of longitudinal ridges, in the transverse ridges being straight and not closely and regularly undulatory, and in the spaces between the transverse ridges being smooth.

B. (?) *fimbriatus* approaches more closely to the carina of *Pollicipes rigidus*, J. de C. Sowerby,[1] from the Gault (Albian), especially to those examples that are more strongly ridged longitudinally, than to the other Jurassic species. *P. rigidus* is distinguished from *Brachylepas* (?) *fimbriatus* by its much finer ornamentation, particularly in the longitudinal ridges, which are very much finer and twice as numerous; the transverse ridges are less regular, and although somewhat undulatory, are not regularly and closely undulatory, neither have they the peculiar goffered appearance as in *B.* (?) *fimbriatus*. Moreover, the transverse ridges are sharp-edged, and the spaces between them are not tranversely ridged as in *B.* (?) *fimbriatus*.

B. (?) *tithonicus* resembles in general form the carina of the Upper Senonian species *Pollicipes fallax*, Darwin (now referred to the genus *Brachylepas* by Dr. H. Woodward). In *B. fallax*[2] the transverse ridges are not nearly so prominent or so regularly spaced, nor have they the beaded ornament on their summits as in *B.* (?) *tithonicus*; the transverse ridges are also much more strongly concave in the middle

[1] J. de C. Sowerby, Trans. Geol. Soc. London, ser. II, vol. iv, p. 335, pl. xi, fig. 6*, 1836; C. R. Darwin, Pal. Soc. Mon. Foss. Lepadidæ, p. 73, pl. iv, fig. 7, 1851.

[2] H. Woodward, GEOL. MAG., Dec. V, Vol. III, p. 341, Figs. 5–7, 1906. This and subsequent references are to published figures of the carina of the different species, and are not necessarily the references to the original description of the species.

and convex at the sides than in *B.* (?) *tithonicus*, and this considerably alters the shape of the basal margin.

B. (?) FIMBRIATUS and B. (?) TITHONICUS, compared with other Jurassic species.

Archæolepas royeri,[1] P. de Loriol (Portlandian = Tithonian), and *A. redenbacheri*,[2] A. Oppel (Kimmeridgian), have quite small and thin-walled carinæ, and are readily distinguished from the above two species by their triangular shape and the absence of transverse ridges.

Pollicipes suprajurensis,[3] P. de Loriol (Portlandian = Tithonian), differs in the more rapidly widening carina, in the smaller transverse convexity, and in the pronounced convexity of its basal margin.

Scalpellum reticulatum,[4] J. F. Blake (? = *Pollicipes*), a Kimmeridgian species, differs in the more rapidly widening carina, in the smaller transverse convexity, and in the strong convexity of the growth-lines; the basal portion of the valve is broken.

Pollicipes quenstedti,[5] von Ammon (referred to *Archæolepas* by Zittel), of Kimmeridgian age, although ridged transversely, has not the prominent equally-spaced transverse ridges, and has a somewhat less acute apical portion.

Pollicipes ooliticus,[6] J. Buckman (Bathonian), differs in having a proportionately much wider base, and in the absence of prominent equally spaced transverse ridges.

P. (?) *lotharingicus*,[7] A. Méchin (Pliensbachian = Charmouthian), differs much in shape, being considerably narrower and more attenuated in the upper half of the carina. It differs further in the absence of prominent, regularly-spaced, transverse ridges, and particularly from *Brachylepas* (?) *fimbriatus* in the absence of longitudinal ridges.

EXPLANATION OF PLATE XXIII.

FIG. 1*a*. *Brachylepas* (?) *fimbriatus*, Withers, sp. nov. External view of carina. × 3 diam. Tithonian, Red Limestone: Stramberg, Moravia.

,, 1*b*. Side view of same.

,, 2*a*. *B.* (?) *tithonicus*, Withers, sp. nov. External view of carina. × 3 diam. Tithonian, White Limestone: Stramberg, Moravia.

,, 2*b*. Side view of same.

The figures in this Plate have, by kind permission of the Keeper, been copied from photographs in the Geological Department of the British Museum, taken by Miss M. B. Chapman.

[1] P. de Loriol, Mém. Soc. Linn. Normandie, vol. xvi, p. 20, pl. iii, fig. 1, 1872.

[2] A. Oppel, Palaeont. Mittheil. Mus. d. k. Bayer-Staates, Stuttgart, 1862, Bd. i, p. 116, pl. xxxviii, fig. 6.

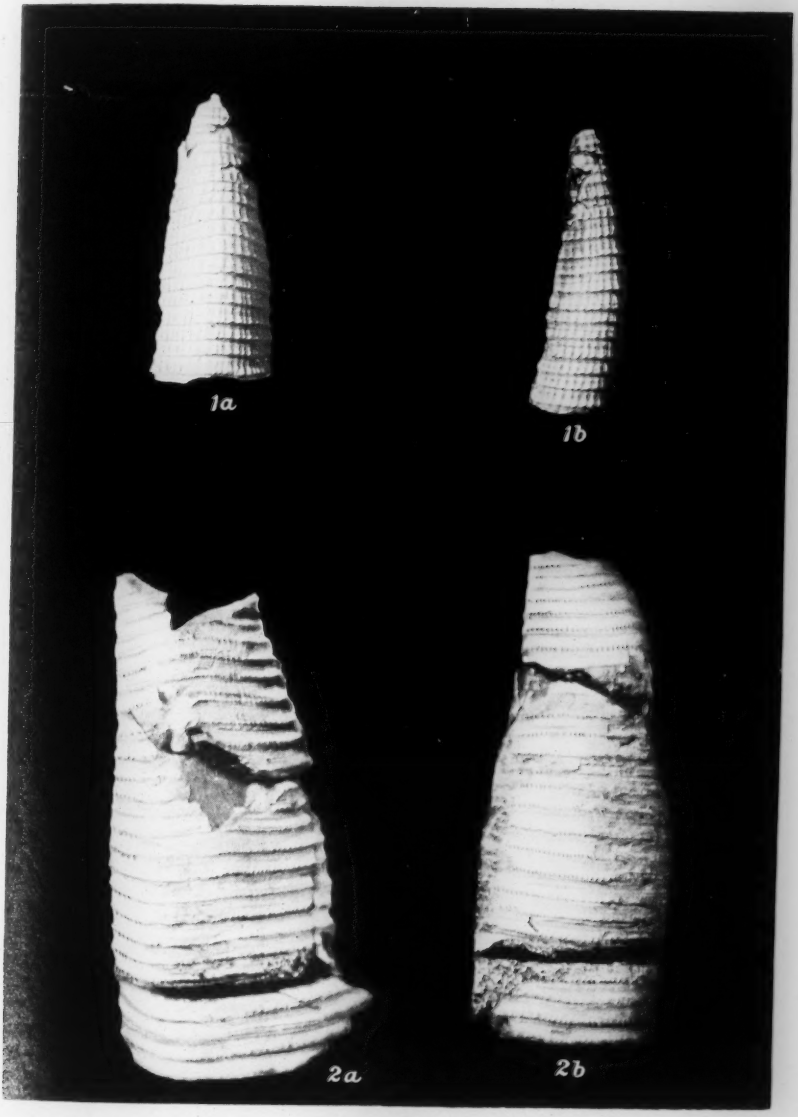
[3] P. de Loriol, Mém. Soc. Phys. d'Hist. Nat. Genève, vol. xxiii, p. 261, pl. i, fig. 1, 1873–4.

[4] J. F. Blake, Quart. Journ. Geol. Soc. London, vol. xxxi, p. 232, pl. xii, fig. 1, 1875.

[5] Max Schlosser, *Palæontographica*, Bd. xxviii, p. 60, pl. viii, fig. 11, 1881.

[6] C. R. Darwin, Pal. Soc. Mon. Foss. Lepadidæ, 1851, p. 50, pl. iii, fig. 2.

[7] A. Méchin, Bull. Soc. Sci. Nancy, ser. III, vol. ii, fasc. i, p. 16, with plate, 1901.



FIGS. 1a, 1b. *Brachylepas (?) fimbriatus*. FIGS. 2a, 2b. *B. (? tithonicus*.
Tithonian : Stramberg, Moravia.

NOTICES OF MEMOIRS.

I.—Bembridge Limestone at Creechbarrow Hill, Isle of Purbeck.[1]

Report of the Committee, consisting of Professor T. McKenny Hughes (Chairman), Mr. H. Woods (Secretary), Dr. J. J. H. Teall, Dr. J. E. Marr, Professor E. J. Garwood, Mr. Clement Reid, Mr. W. Whitaker, and Mr. H. A. Allen, appointed to investigate the occurrence of the Bembridge Limestone at Creechbarrow Hill.

On the Results of the Further Examination of Creechbarrow Hill.

By Henry Keeping.

(*Abridged.*)

In September, 1910, I was sent by Professor Hughes to collect fossils on Creechbarrow, with a view to determining the age of the limestone which caps the hill, and I obtained a sufficient number of characteristic forms to enable me to refer the rock to the Bembridge Limestone. In the report then published[2] I further suggested that there was plenty of room for the rest of the Tertiary beds which might be expected to occur below the Bembridge Limestone, and I published a section in illustration of that view.

A grant from the British Association has since enabled me to ascertain, by means of excavations and borings, the nature of the strata along the flank of the hill.

The details thus obtained were as follows:—

Pit I (*the highest on the east side of the hill*).

	ft.	in.
(*a*) Surface soil.		
(*b*) Mixed clay and gravel with sharp angular flints . . .	3	0
(*c*) Blocks of hard limestone with *Melanopsis* and *Paludina* .	2	0
(*d*) Rubbly limestone. This I recognized as the same as the bed which occurs at the base of the limestone on Headon Hill, where it is rich in mammalian remains. I found here a tooth of *Palæotherium* on my last visit, and we now obtained a good tooth of *Dictulumus leporinus* (Owen)	0	9
(*e*) Caking sand	3	6
(*f*) Dark-brown sand	14	6
(*g*) Light-grey sand with a very large flint at the base. This is on the same horizon as the bed in which Mr. Hudleston found the curiously coated flints which he thought were in situ and passed under the limestone	1	3
	25	0

Pit II.

(*a*) Surface soil.		
(*b*) Clay, sand, and gravel with fragments of weathered limestone at the bottom	16	0

[1] Report communicated to British Association Meeting, Dundee, September, 1912, Section C (Geology).

[2] Geol. Mag., Dec. V, Vol. VII, October, 1910, p. 436.

PIT III.

	ft.	in.
(*a*) Surface soil.		
(*b*) Dirty gravel	3	0
(*c*) Caking sand	3	0
(*d*) Large and small flints	1	0
(*e*) Brown, stiff, sandy clay	3	0
(*f*) Loose flint gravel	2	0
(*g*) Black streaky clayey sand with flint-chips, concretions, and much manganese	7	0
(*h*) Hard irony crust	0	3
(*i*) Clayey sand with perished flints; one large white flint at the bottom of the hole	0	3
	19	6

PIT IV.

(*a*) Vegetable mould	0	9
(*b*) Clay, sand, and gravel with very large flints up to 1 cwt. This much resembles the Middle Headon Venus Bed	9	0
(*c*) Drab sandy clay like that in brickyard; not bottomed	15	0
	24	9

PIT V (*about* 10 *feet below the summit on the west side of the hill*).

(*a*) Surface soil.		
(*b*) Clay with angular flints	2	6
(*c*) Very stiff hardened clay with pieces of rubbly limestone containing much manganese and soot-like patches	9	6
(*d*) Fragments of Bembridge Limestone very rich in fossils. This was where I obtained the chief collection made during my former visit. On this occasion we obtained a good specimen of *Unio*, the first I believe, found at this horizon	2	0
(*e*) Hard crumbling limestone	7	0
(*f*) Sandy clay	9	0
(*g*) Grey sands with quartz pebbles and broken flints. On my former visit I found a large fragment of Bembridge Limestone at a depth of 13 feet not far from this pit	4	0
	34	0

The lowest bed we touched was the drab sandy clay at the bottom of Pit IV, which is the same as that seen in the brick-pit, and the thickness of which I estimate to be not less than 40 or 50 feet. It seems to have been much used for dressing the land, and we found many old pits from which it had been obtained along the west side of the hill. This clay I regard as the equivalent of the Lower Headon formation. The coarse sand, which occurred above this, I take to be the Middle Headon Venus Bed, while the mottled red and green clays or marls which we found about 16 feet below the summit of the hill much resembled the Osborne Series.

Of the part of the hill explored by us I should say that about three-quarters consisted of Oligocene strata and the rest of sand and gravel. There is everywhere evidence of great disturbance of the strata, whether we refer this chiefly to large movements of faulting and overthrust, or the more superficial action of landslips, soil creep, etc.

[We are glad to print the important details of the Creechbarrow strata that have been obtained by Mr. Keeping, especially as they confirm the original discovery of our old friend Hudleston. (See GEOL. MAG., 1902, p. 241; 1903, pp. 149, 197.)—ED.]

II.—A Theory of the Menai Strait.[1] By Edward Greenly, F.G.S.

Ramsay's view of the Strait as a glacial furrow was in the main accepted; but it was shown, from the general glacial phenomena and from soundings, that the middle reach of the Strait cannot be explained in that way. Evidence was adduced to show that this reach was excavated by glacial waters during the recession of the ice at a time when the mutual relations of the ice of the mountain-land and of the sea-basin admitted of the accumulation of a temporary lake. Post-Glacial erosion and subsequent changes of level have completed the bed of the Strait as it now exists.

III.—Note on the Fish-remains collected by Messrs. R. Campbell, W. T. Gordon, and B. N. Peach in Palæozoic Strata at Cowie, Stonehaven.[1] By R. H. Traquair, M.D., LL.D., F.R.S.

The fish-remains from Cowie, Stonehaven, consist of:—

1. Small scutes which are about three times as long as they are broad, slightly convex on one side and correspondingly concave on the other, and apparently pointed at both ends. They seem to me to be referable to the category of Cephalaspidian scutes, only the external ornament, where visible, consists of longitudinal and slightly wavy striæ in place of tubercles. That the species to which they belong, as yet unnamed and undescribed, is pretty certain; but the advent of additional material is necessary before proceeding further in that direction.

2. Several fragments of thin minutely tuberculated plates, which may also be Cephalaspidian, though their nature, indeed, is still problematical.

3. Several specimens of a beautiful *Cyathaspis*, which I herewith dedicate to Dr. R. Campbell, and of which I give a brief diagnosis.

Cyathaspis Campbelli (Traquair).—Shield, ovoid, concave, shallow, broadest part situated behind the point of greatest expanse; covered with stout ridges running in a longitudinal direction, but also tending to converge a little anteriorly and posteriorly. These ridges are also constantly interrupted, so as to give almost a tubercular appearance, the tubercles being comparatively distantly placed, much compressed, and crenulated.

IV.—The Downtonian and Old Red Sandstone of Kincardineshire. By Robert Campbell, M.A., D.Sc.

I.—*Downtonian.*

A thickness of nearly 3,000 feet of vertical or highly inclined strata, formerly included with the Lower Old Red Sandstone, but now regarded as of Downtonian age, intervenes between Craigeven Bay and Stonehaven Harbour. Three groups of beds in this succession may be particularly noted:—

1. At the base of the series there is a thickness of about 200 feet of breccias interbedded with fine red mudstones and made up mainly of fragments of the underlying (?) Upper Cambrian rocks. The basement breccias rest unconformably on the (?) Cambrian. The unconformable junction, which is well seen on the north side of the headland at Ruthery Head, was formerly regarded as a line of faulting.

2. About 20 yards east of Cowie Harbour there occurs a thick belt of grey and greenish mudstones and shales which yield *Dictyocaris* in abundance. From this horizon have been obtained also *Ceratiocaris*; *Archidesmus* sp., and a new genus of Myriopod; (?) larval form of insect; *Eurypterus*, sp. nov.; fragments of scorpion; plant fragments and worm-tracks. Further, a thin bed of reddish sandy mudstone underlying the above series has yielded numerous plates of a new *Cyathaspis*.

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

3. About 60 feet below the *Dictyocaris* horizon there is a thickness of about 40 feet of volcanic conglomerates and tuffs, the presence of which implies that the volcanic activity, which was so marked a feature in the history of this area during the Lower Red Sandstone period, had already been initiated in Downtonian times.

Neither *Dictyocaris* nor *Ceratiocaris* has been found elsewhere in rocks younger than Upper Silurian, and, apart from the occurrence of tuffs, the lithological characters of the above succession recall at once the typical Downtonian rocks of the south of Scotland. The highest beds of the Downtonian pass conformably up into the micaceous sandstone and conglomerates of Stonehaven Harbour which may be considered as the base of the Lower Old Red Sandstone.

II.—*Old Red Sandstone.*

(*a*) *Lower.*—The Lower Old Red Sandstone Series consists of a great thickness of coarse conglomerates and sandstones with intercalated lavas and tuffs. Palæontological evidence is everywhere meagre, but the recognition of a number of well-marked volcanic zones has been of value in elucidating the structure of the area. The lavas include dacite, hornblende-biotite andesites, augite andesites, hypersthene andesites, hypersthene basalts, and olivine basalts. The tuffs are all acid in character. Minor intrusions of presumably Old Red Sandstone age occur in the form of dykes and thin sills of quartz porphyry, biotite porphyry, dolerite, and lamprophyre. The distribution of the lavas indicates that the centres of eruption lay along two lines—one to the east of the present coast-line, the other over the area of Dalradian Schists to the north of the Highland boundary fault.

The coarse conglomerates, which build up a great part of the succession, fall readily into two groups: (1) those in which boulders of quartzites or other 'Highland' rocks predominate; (2) those which are made up almost exclusively of volcanic rocks—volcanic conglomerates. Two points of particular interest may be noted in the former group—the occurrence of boulders of the 'Haggis rock' type of greywacké, and the abundance of boulders of the 'newer' granites, which have been collected even from the lowest conglomerates. The distribution of the volcanic conglomerates points clearly to the denudation of a thick series of rhyolites and acid andesites which must have extended far to the north of the Highland fault.

The chief structural feature of the Lower Old Red Sandstone area is a continuation of the well-known synclinal fold of Strathmore. In Kincardineshire, however, in the district to the west of Elfhill, there intervenes between the syncline and the Highland fault a steep-limbed anticline, pitching out to the south-west. The southern limb of the syncline is traversed by numerous powerful dip faults.

(*b*) *Upper.*—The Upper Old Red Sandstone occupies a small area on the coast in the neighbourhood of St. Cyrus. Although no fossils have been recorded, the lithological evidence—and particularly the occurrence of characteristic cornstones—leaves no room for doubt that here we are dealing with an outlier of the more extensive tract of Upper Old Red Sandstone of Arbroath. In Kincardineshire the Upper Old Red Sandstone is everywhere faulted against the Lower.

V.—On an Actinolite-bearing Rock allied to Serpentine.[1] By A. W. Gibb, M.A., D.Sc.

THIS rock is associated with the intrusion of basic rocks in Belhelvie, Aberdeenshire. Towards the northern end of this mass, which consists of troctolites, serpentines, and allied types, a rock is occasionally

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

met with which differs in some respects from the varieties common in the district. In its most typical development it shows a large number of dark green rounded spots set in a fine felt of paler green colour, full of glancing needles. Most of the specimens show a more or less clearly defined banding or schistosity. The affinities of the rock are somewhat obscure in hand-specimens. But under the microscope the dark spots are seen to represent olivine, which is still partly unaltered, but partly serpentinized, as well as granulitized and drawn out. The rest of the rock is largely made of actinolite in small crystal flakes; there are also present a green spinel, abundant magnetite, and sometimes other ingredients. In most varieties there is no trace of felspar. This rock passes into varieties in which the spots are much less obvious, and finally grades into a rock that might be described as an actinolite-schist.

The exposures of this rock, so far as they have been mapped, lie mostly on the outer fringe of the basic intrusion, and therefore close to the line of junction with the metamorphic rocks into which the igneous rocks have forced their way. From its field relations and its general characters it is clear that it represents a type of the basic rock which has undergone actinolitization on an extensive scale. The original rock from which it is derived must in most cases have been an olivine-enstatite rock, more or less completely serpentinized, or else a very basic troctolite. Although actinolitization is widespread in this, as in other metamorphic areas, a rock of this particular type has not been noted in this locality before. It has nowhere been found in large mass, and seems essentially a marginal phase. The most prominent exposure yet met with is, or was, a clump in a field adjoining the Udny Road, immediately south of 'Skelly-hill Wood'. This exposure has recently been entirely blasted away, and it seemed desirable to make a definite record of its occurrence.

VI.—The Archæan Rocks of Lewis.[1] By B. N. Peach, LL.D., F.R.S., and J. Horne, LL.D., F.R.S.

During 1911 the authors visited Lewis with the view of comparing its Archæan rocks, previously described by Macculloch, Murchison, Heddle, and James Geikie, with the types of Lewisian Gneiss mapped by the Geological Survey along the western seaboard of Sutherland and Ross. The areas examined comprised sections taken at intervals along the east coast from Tolsta Head, north of Stornoway, to near Loch Bhrollum, opposite the Shiant Isles—a distance of about thirty miles; and along the west side from the Butt of Lewis to Carloway—a distance of twenty-five miles. Traverses were made across the island (1) from Barvas on the west to Stornoway on the east, thence over the Eye peninsula to Tiumpan Head; and (2) from Carloway by Callernish to Keose on Loch Erisort, and Stornoway.

A large series of specimens was collected and submitted to Dr. Flett for examination, who has furnished a valuable detailed report showing wherein they resemble and wherein they differ from types described by Dr. Teall in the Geological Survey Memoir on *The Geological Structure of the North-West Highlands of Scotland* (1907). Dr. Flett has arranged the specimens in the following groups: (1) muscovite-biotite-gneiss, (2) biotite-gneiss, (3) biotite-hornblende-gneiss, (4) hornblende-gneiss, (5) pyroxene-gneiss, (6) hornblende-schist, (7) pyroxenite, (8) pegmatite-gneiss, (9) granite-gneiss, (10) mylonite.

In the various sections examined throughout the island, rocks belonging to groups (2), (3), and (4) are the main components of the Archæan

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

Complex. They are intimately associated with each other, and have a common foliation. The muscovite-biotite-gneisses (1) occur together with the biotite-gneisses, but they are not abundant. The pyroxene-gneiss (5) is recorded only from one locality, viz. Dalbeag, near Carloway, where it forms part of a basic mass which is cut by the foliated granite of Carloway (9). The hornblende-schists (6) constitute basic masses in the complex, with a foliation more or less parallel with that of the contiguous gneisses. The relative age of the members of this group has not been definitely ascertained. The pegmatites and pegmatite-gneiss (8) intersect the other components of the complex, but they are sparingly represented compared with the great development of these types on the mainland between Laxford and Cape Wrath. One example of pyroxenite (7) was obtained in the policies of Stornoway Castle. Mylonites (10) are typically developed in certain sections along the eastern seaboard between Tolsta Head and Loch Bhrollum.

In the areas examined, the north-west and south-east strike, referred to by Murchison, is not characteristic of the gneisses of Lewis. It is prevalent immediately to the west of Stornoway, but exceptional in other tracts. In this connexion the observations of Professor James Geikie in the Eye peninsula were confirmed. The dominant strike over extensive areas runs a few degrees east of north and west of south; in certain localities it is north-east and south-west, and in others nearly east and west.

The prevalent types of gneiss closely resemble those to be found on the mainland between Loch Laxford and Cape Wrath, without the great series of acid intrusions. The structure is coarsely granular, or granulitic, the mineral grains being rounded and not elongated. The range of rock types seems to be comparatively limited, for there is a marked absence, in the areas examined, of the pyroxene-gneisses with blue quartz, of pyroxene-granulites, and other basic and ultrabasic materials, which are so characteristic of the Fundamental Complex between Lochinver and Scourie on the mainland. The remarkable series of basic and ultrabasic dyke intrusions in the west of Sutherland has not been detected in Lewis.

The flaggy granulitic gneisses of the Butt of Lewis which appear to run southwards along the belt of high ground between Stornoway and Barvas are of special interest. In structure they closely resemble the Moine gneisses east of the Moine thrust-plane, but they differ petrologically from the rocks of sedimentary origin that form the Moine Series of the Geological Survey. The system of over-folding and the direction of the axial planes of the folds approximate to those found in the Moine rocks on the mainland.

The platy rocks or mylonites, noted by Macculloch, occur along definite lines of movement, trending a few degrees east of north and west of south. Actual thrust-planes have been detected, which are inclined to the south of east at low angles, as if the displacements had been in a westerly direction. Various stages in the development of mylonites from the acid and basic gneisses are represented.

VII.—The Origin of Kopjes and Inselberge.[1] By J. D. Falconer, M.A., D.Sc.

Detached hills, projecting crags, and isolated rocks are features of almost every landscape, and in the moister regions of the globe their origin has usually been correctly assigned to the ordinary processes of denudation. They may arise either through dissection of earlier

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

plateau-surfaces, as frequently in the case of detached flat-topped and pyramidal sandstone hills, or by the weathering out of the more resistant units where the surface is composed of rocks of different degrees of hardness, as in the case of escarpments and of detached crags and hills of igneous rock. The kopjes and island mountains of the warmer temperate and tropical regions are essentially of similar origin, but on account of the present climatic conditions being in many cases different from those under which they were formed, their actual mode of origin has given rise to considerable discussion. A striking feature of these kopjes and inselberge is that they rise at intervals from an apparently level or gently undulating plain, which in most, if not all, cases should be regarded as a former base-level of erosion. The typical kopjes of South Africa are of sandstone, shot with veins and dykes of igneous rock, which has given them the necessary power of resistance to the agents of erosion. The old crystalline regions of Africa, however, are dotted with domes and turtlebacks of granite and detached groups of granite hills, which represent the more resistant elements of the crystalline complex. Some of these isolated hills possess flattened caps of weathered rock, and it seems probable, therefore, that the sculpturing of the original crystalline surface was due, not so much to the direct erosion of the unweathered rocks, as to the effect of periods of elevation and erosion following upon periods of decomposition in situ at base-level. As the result of erosion a somewhat irregular surface would be produced, but a slight subsequent negative movement would suffice for the obliteration of the minor irregularities and the consequent accentuation of the less weathered portions of the surface. The repetition of such a cycle would lead to the increased prominence of the earlier hillocks and the formation of others of lower level. It has been suggested that a landscape with inselberge is of desert origin, but the various phenomena can be explained more readily as the result of weathering and erosion during successive small oscillatory movements of a regional character in the neighbourhood of base-level.

VIII.—The Heavy Mineral Grains in the Sands of the Scottish Carboniferous.[1] By T. O. Bosworth, B.A., B.Sc., F.G.S.

THESE observations were made at the commencement of an investigation which the author has now no opportunity to carry on.

The chief heavy grains are :—

Garnet, which, though in some sands practically absent, in others is in such excessive quantity as to almost mask the presence of other grains.

Zircon, always present, and sometimes the most abundant species.

Magnetite, always present.

Tourmaline, always present.

Rutile, always present, but varies widely in quantity and characters.

Staurolite, often present, but not plentiful.

Anatase, occasionally present in noticeable amount, as well-formed plates of steel-blue colour.

Barytes, found in a few cases in large amount. It is probably a cement, though well-formed crystal plates occur. Sandstones containing this cement are very hard. I find it in several building stones.

Characteristic of all the grains is their angularity. The garnets have the dodecahedral cleavage developed out in a remarkable manner,

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

so that the grains have elaborate zigzag shapes with innumerable corners and edges. The contrast between these heavy grains and those in desert sands is much more marked than in the case of quartz.

The heavy mineral contents prove the sands to belong to at least two entirely different kinds :—

(*a*) Sands in which the heavy mineral grains consist mainly or largely of garnets.

(*b*) Sands in which garnet is absent or scarce.

Vertical and Lateral Distribution.—The amount of evidence yet collected is only sufficient to be suggestive of the kind of results which may be obtained.

In the following list o denotes garnetiferous, × denotes non-garnetiferous. (Measurements in bore sections are actual, and are not corrected for inclined strata.)

Red Measures.

o	Rutherglen.	

Coal-measures.

o	Cambuslang	above Humph Coal.
o	Chapelhall, Shottsburn	24 feet above Lower Drumgray Coal.
o	Chapelhall, Shottsburn	just above Lower Drumgray Coal.
o	Chapelhall, Shottsburn	" " "
o	Fauldhouse Quarry	above Crofthead 4 feet Coal.
×	Chapelhall, Shottsburn	below the Coals, faulted, and near Millstone Grit.

Millstone Grit.

×	Bilston Burn, near Edinburgh	Roslin Grit.
×	Glasgow, Blochairn Quarry	above fireclays.
×	Muirhouse Bore, Lanarkshire	depth 30 feet.
×	Muirhouse Bore, Lanarkshire	depth 174 feet.
×	Levenseat	above Curdley Ironstone.
×	Balfour Bore, Fife	12 feet above Levenseat Limestone horizon.
o	Bilston Burn	6 feet above Castle Carey Limestone horizon.

Carboniferous Limestone Series.

o	Balfour Bore, Fife	36 feet below Calmy Limestone horizon.
o	Bilston Burn	100 " " "
o	Balfour Bore	360 feet above Index Limestone.
×	Giffnock	270 " " "
o	Balfour Bore	150 " " "
o	Bilston Burn	12 " " "
o	Bishopbriggs, Hunters' Hill	just " " "
×	Kirkintilloch	40 feet below Index Limestone.
o	Linlithgow	200 " " "
×	Bilston Burn	540 " " "
×	Balfour Bore	798 " " "
o	Balfour Bore	1,242 " " "
×	Balfour Bore	1,374 " " "
o	Bilston Burn	5 feet below Hosie Limehouse horizon.
×	Bilston Burn	10 feet above North Greens Limestone.

Calciferous.

×	Milngavie	above the Traps and below Hurlet Limestone.
×	Burntisland, Grange Quarry	about Burdiehouse horizon.
×	Hailes Quarry.	
×	Craigleith.	

Conclusions and Suggestions.—The sands containing such an extraordinary quantity of angular garnet have been derived from the Highland schists to the north and north-west of the basin, whilst the sands devoid of garnet are likely to have come from the north-east, east, or south.

It may be possible by a study of the heavy mineral grains and of the current-bedding, and the thickening and thinning of the beds, to subdivide the whole of the Carboniferous accumulation into a number of great lens-shaped or wedge-shaped bodies of sediment, which have been introduced from various directions and are interdigitated in a complex manner. These great lenticles might be expressible on maps, and might be helpful in explaining the lateral changes and the distribution of the coals.

IX.—A Mull Problem: The Great Tertiary Breccia.[1] By E. B. Bailey, B.A., F.G.S.[2]

THERE is in Eastern Mull a great breccia formation, with, in places, several intercalated rhyolite lavas. The breccia consists for the most part of an unbedded assemblage of blunted blocks and fragments of gneiss, granophyre, gabbro, and basalt, often associated with rhyolitic debris, for which latter a truly volcanic origin can be readily admitted. The problem is whether the non-rhyolitic material of the breccia has been derived through explosion or erosion. If the former alternative is adopted, many of the breccia outcrops must be regarded as marking the sites of volcanic vents, since in several cases the boundaries of the breccia are frankly transgressive. At the present time it is considered that the evidence favours an alternative view, that the breccia is an unconformable formation later than the basalt lavas of Mull, and that its transgressive relations are due to erosion which preceded and accompanied its formation. The basalt lavas of Mull have been violently folded into a series of anticlines and synclines, and it is in one of these synclines that the main outcrop of breccia in Eastern Mull is preserved, with every appearance, moreover, of approximate conformity to the surrounding basalts. Here it is difficult to escape the conclusion that the breccia is a thick layer overlying the basalts and folded with them. Alongside of the syncline is an abrupt anticline, in which are exposed all the rocks commonly recognizable as fragments in the breccia. The anticline has a core of gneiss, flanked locally by upturned Mesozoic sediments, and these by steeply dipping basalt lavas; intruded, chiefly into the gneiss, are granophyre and gabbro. Patches of breccia, distributed without reference to geological structure, occur in this anticlinal region, and rest upon or against all the rocks mentioned above. Although no positive conclusion can be drawn, it is suggested that the breccia has in large measure resulted from erosion, which operated during the period of upheaval of this and neighbouring anticlinal ridges.

X.—The Sequence of Volcanic Rocks in Scotland in relation to the Atlantic-Pacific Classification of Suess.[1] By John S. Flett, M.A., D.Sc., F.G.S.

THE recognition of two great families of igneous rocks, the Atlantic and the Pacific, and their relation to certain types of earth-movement, which we owe to Harker, constitutes one of the greatest advances in rational petrology.

In Scotland we may take the Carboniferous volcanic rocks as typical Atlantic, while the volcanic rocks of Lower Old Red Sandstone age are characteristic of the Pacific group. We may add to the Atlantic two other series, the Permian or late-Carboniferous volcanic rocks of Ayrshire and East Fife and the nepheline-basalts (presumably Tertiary) of Caithness, with their associated camptonites and monchequites.

The Tertiary volcanic rocks of the Hebrides are Atlantic, and are associated with movements of Atlantic types. There is much reason in ascribing also to this period the north-west dykes, so abundant in Scotland, which contain not a few nepheline-bearing rocks.

The remaining volcanic rocks of Scotland are of distinct type. They comprise the Tayvallich lavas (perhaps pre-Cambrian), the Upper Cambrian volcanic rocks of the Highland border, and the Silurian (and

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

[2] With the permission of the Director of the Geological Survey.

Ordovician) lavas of the Southern Uplands. Pillow-lavas with keratophyres, etc., characterize this group. They are not connected with movements either of Atlantic or of Pacific kind, and may be placed in a special family.

XI.—On Buckled Folding.[1] By G. Barrow.

A NUMBER of descriptions have been published of portions of areas of regional crystalline metamorphism in which the dip of the bedding, or in some cases the dip of the foliation, is described as being at a low angle over a considerable area. These descriptions are at times so worded as to convey the impression that this represents the original and but slightly disturbed bedding of the altered sediments. Experience is gradually proving that the altered sediments in such areas are always intensely folded, and the detailed examination of the Highlands suggests that in place of these long-continued low dips being due to small disturbance, they really represent the most complicated form of structure, for which the name of 'buckled folding' is suggested.

The best-known illustration of the phenomenon in this country is afforded by the gneissose-flagstones or Moine gneisses. The deceptive nature of the dips in the rocks was soon recognized by the officers of the Geological Survey of Scotland, who found that in cliff sections the beds really ascended the cliffs by a zigzag course to which the term 'lightning-structure' was applied.

The mode of production of this 'zigzag' structure can be traced on the cliffs between Stonehaven and Muchalls, in Kincardineshire. The rocks in these cliffs consist of alternations of grits, gritty shales, and shales, becoming more and more crystalline as we proceed northward. Nearer Stonehaven the bands of grit may be seen to ascend the cliffs in an unbroken or unbent course from bottom to top, having a high dip in a northerly direction. The limbs of the folds are thus isoclinal and unbent. But as we proceed northwards the course of the grit bands up the cliff face is no longer straight; a small overfold or 'buckle' is developed on it. At first only one is seen in the whole height of the cliff; further north two occur; then three, and so on, till at last they are so close together that the still straight portion of the fold is little, if at all, longer than the 'buckled' or overfolded portion. If the upward course in the cliff of each grit band be carefully followed it will be found that the oncoming of this 'buckling' structure does not alter the dip of the band as a whole; it still descends at much the same angle, only it pursues a more zigzag course. The overfolds or buckles all face the same direction right up to Muchalls, and a little consideration will show that this 'buckling structure' must have been produced after the isoclinal folding was completed. There is thus no evidence to suggest that the rocks in which the buckling structure has been developed should be separated as a different series from those in which it does not occur. In the interior of the South-Eastern Highlands this structure is present in all but the southern margin of the area, till we reach the first outcrop of the Highland quartzite, where the buckling rapidly ends and the earlier isoclinal folding is left unaltered. For a distance of some seven or eight miles the buckling structure is either very rare or absent, but it sets in again in the quartzite close to Braemar. It is there also shown both by the marginal sandy beds, known as the Moine gneisses, and the dark schist next them. There also is no justification for separating the beds with the superinduced 'buckling structure' from those without it, as has been generally done. A key to the connexion between the 'buckled' and 'non-buckled' areas occurs in the ground about Shiehallion and to the north (Sheet 55, Scotland). At Shiehallion we have the quartzose beds forming the

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

margin of the quartzite, and containing the boulder bed and the limestone close by; further north we have the same group again. In the first case we have isoclinal folding; in the second, buckled folding, or Moine gneiss.

REVIEWS.

I.—The Permian Amphibia and Reptilia of North America.

THE recent appearance of three[1] very important works dealing with the fauna of the 'Permian' of Texas and the traces of that fauna which have been found in New Mexico, Pennsylvania, etc., enables us for the first time fully to appreciate its importance and its many remarkable features. Evidence has been recently accumulating to show that this fauna is really largely of Upper Carboniferous age. Williston has pointed out that the fauna is an isolated one, apparently developed quite out of touch with the rest of the world; and although Broom has shown that it is composed of fundamentally the same stocks as the Permian fauna of South Africa, there is no doubt that his general argument is correct.

It is a very remarkable group of animals which on a ground plan of very primitive structure have built up astonishing specializations, so much so that types like *Cacops*, *Dimetrodon*, and *Edaphosaurus* are amongst the most bizarre animals known. These animals, and many others, seem to exhibit all the features which usually occur in the last individuals of a race: they are phylogerontic, and it is improbable that they left any descendants.

The 'Texas' amphibia and reptiles are then in general precociously specialized examples of the early stocks which in South Africa slowly developed along many lines and gave rise to the mammalia amongst other groups. In the light of these ideas it is of interest to examine some of them in more detail. *Diplocaulus*, now nearly completely known, is an extraordinarily specialized type with an enormous flat head, much produced over the ears, with a slender body and very reduced pectoral limbs. Nothing like it is known elsewhere, but it seems to be a terminal member of the line of Microsauria represented by *Ceraterpeton* and *Diceratosaurus*, which occurs in Europe and North America.

The imperfectly known *Trimerorachis* is a rather unspecialized type, interesting because of its close similarity with the South African Upper Permian *Bothriceps Huxleyi*, now more completely known. The large and very well-known *Eryops* is a specialized representative of a type represented in Europe by *Actinodon*, and in South Africa by *Rhinesuchus* or *Myriodon*, a type whose structure as completely shown by specimens in the Pretoria Museum is thoroughly Eryopid, although much more generalized.

The extraordinary type *Trematops*, very reptilian in appearance, has no recognizable allies elsewhere, and the still more remarkable

[1] E. C. Case, *A Revision of the Amphibia and Pisces of the Permian of North America*, Carnegie Institution, Pub. 146, Washington, 1911; *A Revision of the Cotylosauria of North America*, Carnegie Institution, Pub. 145, 1911. S. W. Williston, *American Permian Vertebrates*, University of Chicago Press, 1911.

Cacops and *Dissorophus*, 'the Batrachian Armadillo,' break one of the diagnostic characters of their class by having a sacrum of two vertebræ. The rhinencephalic chamber of the former type is no doubt formed by a sphenethmoid, a bone which is shown without the least possibility of doubt in *Myriodon*.

The Cotylosauria, the most primitive of reptiles, are represented by a very large number of families and genera, all unique and many remarkably specialized. *Seymouria* is perhaps the most interesting of them; it has a skull which cannot be excluded by any definition which can be framed to include all types of temnospondylous amphibia, united to a body which in the loss of the cleithra and posterior coracoidal elements of the pectoral girdle is specialized, but which has only a single sacral vertebra! Four other types are represented by complete skeletons which show a very wide range of structure and adaptation, together with the preservation in some of them of primitive features, such as the wide ribs in the pectoral region which are so common in the large Stegocephalia.

Williston gives an admirably complete account of the structure of *Casea*, a new type represented by several skeletons found closely associated with *Varanosaurus* and *Cacops* in a bone bed unparalleled in the Permian of any other part of the world. Unfortunately the sutures in the skull are not visible, and its systematic position is still quite uncertain. *Varanosaurus*, represented by several skeletons in the same deposit, is of great interest. In its build and to some extent in its structure it is very reminiscent of the lizards. The group to which it belongs, the Poliosauridæ, is very well represented in the Texas fauna, and is regarded by Case, and, if I understand him rightly, by Williston as including primitive members of the Pelycosauria, the long-spined reptiles belonging, as Broom has shown, to the Therapsida, the group which includes the mammal-like reptiles so well known in South Africa. It is undeniable that they do show many resemblances to this order, but their differences in many important features are so great that it seems improbable that they can really be at all intimately connected with them. Examination of the only known skull of the European *Protorosaurus* and of the skeleton of that type shows no characters which are inconsistent with a close relationship between it and *Varanosaurus*, and a very similar little reptile occurs in the South African Permian. The further exploitation of this fauna and the completion of our knowledge of little-known types is the most interesting problem before the American fossil Herpetologists, and is now being continued by Professors Williston and Case with very great and deserved success.

II.—The Geology of the Districts of Braemar, Ballater, and Glen Clova. By George Barrow, F.G.S., E. H. Cunningham Craig, B.A., F.G.S.; with contributions by L. W. Hinxman, B.A., F.R.S.E. 8vo; pp. vi, 138, with 7 plates. Edinburgh, 1912. Price 2*s*. 6*d*.

THIS memoir is descriptive of the Scottish one-inch Geological Survey map, Sheet 65. A glance at the map, which is clearly and brightly colour-printed, shows that the area is made up almost

wholly of Highland schists, and of large tracts of granite, including the great central mass of Balmoral Forest with Lochnagar, 3,552 feet. Smaller portions of ground are formed of diorite, lamprophyre, serpentine, etc.

Scattered irregularly about the area are glacial deposits of Boulder-clay, sand, and gravel; also much peat, which is "wasting away in many places, owing to the effects of the east winds in spring". Terraces of valley gravel border the Dee, which traverses the district by Ballater, Balmoral Castle, and Braemar.

The memoir is accompanied by some excellent views of rock structures, but neither map nor memoir contain any sections to illustrate the structure of the country. Even a section showing the profile of the ground, with the outcrops coloured near the surface, in the manner adopted by Jukes, would have been useful and instructive. To complete a section to sea-level would no doubt have been impossible even in diagrammatic form. Moreover, as the Director points out in his preface, the metamorphic rocks are so intensely folded and invaded by igneous intrusions of different ages, that the authors of the memoir, and their colleagues in adjacent areas, differ greatly with regard to the succession of the sedimentary schists (quartzites, limestones, etc.), and with regard to the origin and history of the stages of metamorphism. To the petrographical features of the area the main portion of the memoir is naturally given, and it includes an account of the cairngorms for which the northern granite masses are noted. The local search for stones, however, "has been discontinued for many years, the importation of cheap foreign stones from Germany and Brazil having practically killed the demand." It is noted that the limestones are rich in minerals, developed by thermal metamorphism, and well known to collectors. Very fine examples of glacial action are exhibited by the ice-scratched rocks, the moraines, and the other glacial gravels in the Dee Valley and its branches.

III.—Sur la Diversité Génétique des Montagnes Eruptions. By A. Stübel.

Translated from the German by W. Prinz and C. Van de Wiele. Bruxelles, Acad. Roy de Belgique, 1911. 4to; pp. 70, with plate and figures.

AN introductory note explains that arrangements were made by the Académies Royales de Belgiques in 1903 for the publication in French of this paper by the late Alphonse Stübel. The matter was delayed, however, and meanwhile Professor Prinz, who had undertaken the translation, died, leaving his manuscript incomplete. Under these circumstances Dr. Van de Wiele has carried the work through.

The paper begins by pointing out that the great majority of volcanoes are extinct. From this the conclusion is drawn that volcanoes are supplied from strictly local magma-basins, and not from a unique central reservoir.

The next point submitted is that all volcanoes, whether active or extinct, are of comparatively recent, that is, of post-Cretaceous date. As this statement is likely to cause the reader unnecessary trouble it

is unfortunate that it was not defined more precisely; thus it would have been preferable, in every way, merely to have pointed out that, during Tertiary times, volcanoes established themselves in many regions where previously, for long ages, there had been no trace of igneous activity. The pith of the argument, developed from this text, is that the initiation of a volcanic regime must be a very different affair from its continuation. Lyell's philosophy is discarded, and in its place we are asked to accept speculation of a kind not easy to test by direct observation.

It is claimed that the volume of magma emitted as lava or agglomerate during any particular eruption must be proportional to the resistance overcome during the eruption. The actual initiation of a volcano is therefore accompanied by a very extensive extrusion of magma. In fact Stübel regarded it as logically certain that volcanoes are in the main *monogène* structures, each resulting from the eruption which gave it its birth. That *monogène* volcanoes do exist is of course well known, since Monte Nuovo and other historical examples may be cited; the novelty of Stübel's position resides in his belief that volcanoes are all of them essentially *monogène*, though in certain cases their structure may be considerably modified and obscured by later *polygène* accretions.

Topographical considerations are exalted to the position of prime importance in deciphering the life-history of volcanoes. Thus an acute cone with a relatively small crater is regarded as the only form attainable by a *polygène* volcano. A flattened dome or cone on the other hand indicates a *monogène* structure. Such a dome or cone may arise either through a process akin to bubble-blowing, producing a mass with a liquid interior enclosed in a solid cracking crust, or else through the rapid superposition of lava-flow upon lava-flow, with or without intercalations of agglomerate. *Monogène* volcanoes built on this latter plan are supposed to have a comparatively flat stratification, and to owe their conical form merely to a gradual exhaustion of the subterranean reservoir in each individual case, and to the consequent curtailment of successive outpourings of lava. An interesting suggestion places the origin of the parasitic cones of Etna in the body of the volcano, and not in its almost exhausted deep-seated reservoir.

A *monogène* cone, arising in the manner indicated above, may not have a crater at all, but on the other hand it may have one of relatively immense size. An eruption having spent its force, and nearly or quite emptied its limited magma-basin, is frequently brought to a close by an episode of rapid retreat, and the unconsolidated material of the central part of the cone flows or tumbles back into the pipe and so leaves behind a gaping caldera. This supposed connexion between calderas and the *monogène* origin of volcanoes is the point most strongly emphasized by the author. His conclusions are supported by an appeal to the moon, where the caldera form of crater is typically developed. The regular recurrence of the phenomenon in this case does seem to favour some simple and uniform explanation such as is afforded by the theory of the *monogène* eruption; but one cannot forget the uncertainty as to whether lunar craters

are in truth volcanic, not to mention the certainty that the gravitational conditions under which they originated must have been very different from those encountered on the face of the earth.

A large part of the paper is devoted to the classification and discussion of volcanoes on the principles outlined above. There are throughout abundant and well-executed illustrations.

E. B. Bailey.

IV.—Annual Report of British Museum.

British Museum (Natural History).—Reference is made in the British Museum Return for the year 1911 (H.M. Stationery Office, 1912) to the use of the site on the north of the Natural History Museum, and the following paragraphs are of considerable interest:—

"As a result of further correspondence and of several conferences between representatives of the Departments concerned, a settlement has been arrived at, under the terms of which the boundary of the Natural History Museum as adjusted in 1899 has been secured to the Trustees. By the settlement the demolition of the existing Spirit Building has been avoided, and accommodation for the Geological Survey and the collections at present in Jermyn Street will be provided on ground south of the boundary line of 1899. The buildings for the Survey offices and the collections (while communicating with the Science Museum) will be in connection with and form a part structurally of the eastward extension of the Natural History Museum, and will be so arranged as to fit that extension when it is eventually built. A Lecture Theatre, which will be under the control of the Trustees but available for joint use by both Museums, forms part of the scheme."

"The Trustees in assenting to provide this accommodation for the [stratigraphically arranged] Geological Survey collections believe that the arrangement will be of great advantage to students and others interested, since these collections will thus be continuous with the part of the Natural History Museum in which are arranged the Systematic Palæontological and Mineralogical collections."

We note also that this year the Swiney Lectures are to be delivered in December and January, instead of in November, and Dr. Jehu's subject is to be "The Record of Life as revealed in the Rocks".

V.—Cambridge County Geographies.—Two more volumes have reached us. One on Lanarkshire, by Mr. F. Mort (1910), has been unfortunately overlooked. It contains good descriptions of the physical features, with views of the Leadhills, the Falls of the Clyde, and a diagram illustrating the pre-Glacial channels of the river. There is a brief account of the geology, more particularly in reference to the Coal-measures, and illustrated by a view of fossil trees at Whiteinch, near Glasgow. The glacial drifts are described, but no reference is made to the fossil shells of the Clyde Valley Beds. Lead-mines, the gold of Clydesdale, the coal and oil-shale, are duly mentioned in the section on "Mines and Minerals"; and we are glad to see the name of A. C. Ramsay in "the Roll of Honour".

Radnorshire (1912), by Mr. Lewis Davies, is described as a pastoral county with many sheep-walks, with no coal, no sea-coast, and no river of commercial utility, but formed of valleys, moorlands, and a mountainous tract, known as Radnor Forest. Many good views of the physical features are given, including the great artificial lake of the Caregddu Reservoir in the Elan valley constructed for the water-supply of Birmingham. The geology relates almost wholly to Ordovician, Silurian, Old Red Sandstone, and Igneous rocks. Brief accounts of them, of glacial phenomena, of mineral springs, and stone quarries are given.

VI.—Brief Notices.

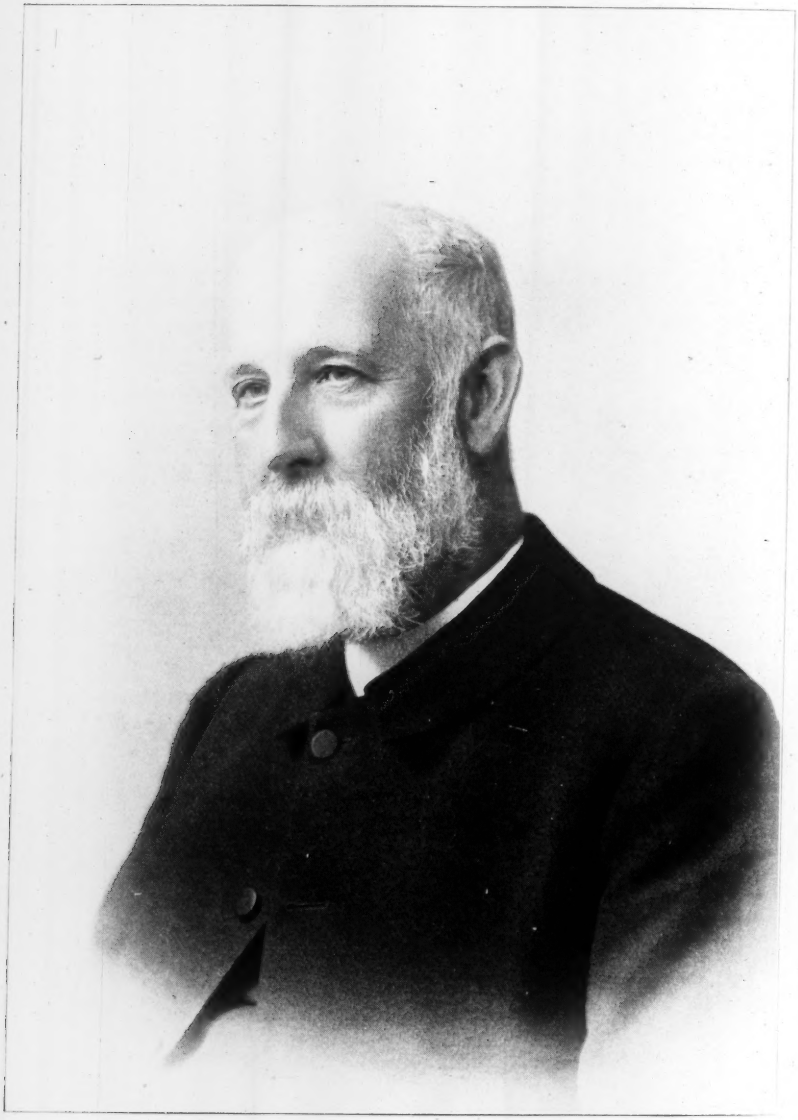
1. North of England Geology.—Some points of general interest are mentioned in a paper on "Lamprophyre Dykes in Long Sleddale, Westmorland" by Mr. Alfred Harker in the September number of *The Naturalist*. The bearing of these dykes is E.N.E., directly towards the Shap granite, 4 miles distant, and one peculiarity is the occurrence of numerous small spherical structures, the result of oozing-in of the final residual magma (wholly felspathic in composition) into steam-cavities. The same part contains a popular geological account of "The Evolution of Bridlington", by Mr. T. Sheppard, who contributes also an account of a lithographed map of South Yorkshire by William Smith, the "Father of English Geology". This map, dated 1819, and reproduced by Mr. Sheppard, has hitherto escaped record.

2. Geological Map of North America.—Under the title Geologic Map of North America the United States Geological Survey has published (dated 1911) a new and much improved edition of the map described by me in the Geological Magazine for 1906, p. 564. The price of the complete map in four sheets is 75 cents or 3*s*. carriage free. The scale is 1 : 5,000,000 or 78·9 miles to 1 inch. In the first edition only twenty-five divisions of rocks were shown. In the new edition forty-two divisions are indicated. Another improvement is the insertion of additional place-names, which enable one to identify localities better. Several of the blank spaces in the first edition are now geologically coloured, e.g. Nevada, Idaho, California, Arizona, New Mexico, Baja California, Yukon, and part of Alaska. One cannot help envying the Americans, whose Government, unlike our own, supplies such excellent maps at so low a price.—B. Hobson.

CORRESPONDENCE.

THE DEVONSHIRE CHALK CLIFFS.

Sir,—I recently spent four days running over the Devonshire chalk cliffs with the help of Dr. Rowe's admirable guide, and it seemed to me that he had not done quite full justice to those west of Branscombe Mouth.



The Rev. R. ASHINGTON BULLEN, B.A. (Lond.) F.L.S. F.G.S., etc.

He attributes all the flinty chalk seen to the west of the bluff in Branscombe West Cliff, described on p. 25, to the *Rhynchonella Cuvieri*-chalk, except for the tops of the first two or three bluffs. The latter are easily recognizable and all lie well to the east of the 'Camp' on Berry Cliff. But in the south-west face of the 'Camp', about 20 yards east of the cart track leading into the undercliff, there is a bluff quite 25 feet high accessible from top to bottom and composed exclusively of normal (flinty) *Terebratulina gracilis*-chalk, and there are four similar bluffs, first one by itself, and then three close together, in the cliff some way further west. Again, just east of the fence which runs down the cliff under Littlecombe Hollow there is a bluff which is probably continuous with two small exposures a few feet eastwards of it, the higher of which is composed of normal *T. gracilis*-chalk. The estimate of 60 feet of flinty *R. Cuvieri*-chalk, if based on the assignment to that zone of all the flinty chalk seen beyond Littlecombe Hollow, may therefore be excessive.

These exposures of *T. gracilis*-chalk are not expressly mentioned in the very full official account of these cliffs given in *The Cretaceous Rocks of Britain*, but it may be intended to cover them.

Incidentally I may add that the very curious *Metopaster cornutus* occurs in the flintless as well as in the flinty *R. Cuvieri*-chalk, though the reverse might have been expected.

R. M. Brydone.

27 Twyford Mansions, Marylebone Street, W.

October 9, 1912.

OBITUARY.

THE REV. ROBERT ASHINGTON BULLEN,

B.A. (Lond.), F.L.S., F.G.S., etc.[1]

Born June 11, 1850. Died August 14, 1912.

(WITH A PORTRAIT, PLATE XXIV.)

It is with sad regret we record the loss of our valued friend Mr. Ashington Bullen, who passed away suddenly on August 14, 1912, in his 63rd year.

Born at St. George's, Bermuda, on June 11, 1850, he had but a short acquaintance with his birthplace, his parents returning to England with their children when he was only 6 years of age. That he retained a love for his birthplace is shown by his making a special expedition to the Bermudas and subsequently publishing a very interesting account of the geology of the group (see Geol. Mag., 1911, pp. 385–95 and 433–42), very fully illustrated.

R. A. Bullen settled with his parents on the south coast and was sent to a private school at Gosport, where he received his early education,

[1] Mr. Bullen's death was recorded in the September Number of the Geol. Mag., p. 432.

and acquired a love for the sea and of Natural History which he never lost. It was originally intended that he should be prepared to enter the Civil Service, but by the force of circumstances he became instead a schoolmaster and continued his own studies privately, taking his B.A. in London University in 1873. He continued teaching after he was ordained in 1875; indeed, until 1883, when he became a curate. His first duty was at St. Peter's, Croydon (1875–9); thence he was transferred to Farleigh, Surrey (1879–80).

On December 19, 1855, Mr. Bullen married Miss Lloyd, daughter of Mr. Edward Lloyd, of Delahay Street, Westminster. He leaves his widow, one son, Robert Edward, and two daughters.

In 1883 he had the good fortune to be appointed curate to Archdeacon Farrar at St. Margaret's, Westminster, and held office until 1888, when he became Vicar of Shoreham, Kent, a preferment which he held until 1896. This was a peculiarly delightful period of Mr. Bullen's life, for it brought him into close personal contact and friendship with Sir Joseph Prestwich, who had for some years taken up his residence at Darent Hulme, Shoreham, Kent, an ideal country house for a man of science to retire to, after a long and active life. Here, for eight years, Mr. Bullen had the happiness of constant intercourse with one of the greatest geologists of the last century, and devoted many rambles over the Chalk Downs in search of flint implements and in discussing the age and extent of the old high-level gravels to which Prestwich devoted much of his latest years. In Lady Prestwich also Mr. and Mrs. Bullen found a most delightful and intellectual friend and neighbour.

From the influence of Sir Joseph Prestwich, Mr. Bullen took up and carried out a most valuable series of researches, which continued up to August last, in many localities where fossil land and freshwater Mollusca could be met with, and especially those associated with the remains of early Man, the early Plateau Gravels, the ancient prehistoric places of interment, and the implements of flint and bone identified with Palæolithic man. The titles of these papers are given at the end of this notice. Much of the spirit of scientific research, inspired by Prestwich, will be found embodied in the little volume on the prehistoric remains discovered at Harlyn Bay, which were very carefully figured and described by Mr. Bullen, a third and greatly enlarged edition of which appeared this year.

His papers on the Æolian deposits on the Coast of Étel; fossil Mollusca, Alcadia (Mallorca); on Manresa, Cataluña; and the Bermuda Islands (1911) specially merit attention.

Shortly after the death of Sir Joseph Prestwich (which occurred June 23, 1896) Mr. Bullen became Rector of Little Stukeley, Hunts (1898–9); and subsequently Rector and Vicar of Wisley, Pyrford, Surrey (1901–5). After resigning the living at Pyrford he made his home first at Hurstpierpoint, Sussex, and later at Englemoor, Heathside, Woking; devoting much time to the work of the various scientific societies to which he had become attached, and in travelling in France, Italy, Spain, and elsewhere.

The death of his second daughter (Miss Evelyn Bullen) in February,

1910, induced him to remove to Hilden Manor, Tonbridge. In 1912 he made a voyage to the Grand Canary, and was, indeed, contemplating a second voyage, with Mrs. Bullen, preparatory to publishing an account of the geology and fossil shells of those islands at the time of his death.

He joined the Geological Society in 1891, the Geologists' Association in 1893, the Malacological Society in 1897, the Linnean in 1899, and the Zoological Society in 1911. He was also a Fellow of the Royal Astronomical Society, and a member of the Selborne Society and the South-Eastern Union of Scientific Societies. It is to this last-named Society's Hon. General Secretary, Dr. Wm. Martin, M.A., F.S.A., that we are indebted for permission to reproduce the portrait (Plate XXIV) of Mr. Bullen which accompanies this notice.

An enthusiastic lover of Nature, an untiring worker, a faithful friend in time of need, his loss will long be felt by a very wide circle, to whom he was endeared by his unostentatious kindness and liberality.

List of Publications by the Rev. R. Ashington Bullen.

1894. "Shells from Portland Rubble Drift": Geol. Mag., pp. 431–2.
1898. "Fossil Non-marine Mollusca, Dover": Proc. Malac. Soc., pp. 162–5.
"The Authenticity of Plateau Implements": Nat. Sci., xii, pp. 106–11, pls. iv–vii.
1899. "Land-shells from Holocene deposit, Horseshoe Pit, Colley Hill, Reigate": Proc. Malac. Soc., iii, pp. 326–9.
1900. "Shells from Portland Rubble Drift": Geol. Mag., pp. 286–7.
1901. "Eolithic Implements": Geol. Mag., pp. 426–7; Journ. Vict. Inst. London, 1900, pp. 1–29, figs. and pls. i–vii; 1901, pp. 191–215.
Harlyn Bay and the Discoveries of its Prehistoric Remains. pp. 1–96, with 18 plates. 1st ed., 1901; 2nd ed., London, 1902; 3rd ed., Harlyn Bay, Padstow, 1912.
"Pleistocene Mollusca from Raised Beach Deposits, Perim Island": Proc. Malac. Soc., pp. 254–5.
"Note on Well-section at Dallinghoe (Suffolk)": Abs. Proc. Geol. Soc., 1900–1, p. 78; Q.J.G.S., lvii, pp. 285–7, 1901.
1902. "Notes on Holocene Mollusca from North Cornwall": Proc. Malac. Soc., v, pp. 185–8.
1903. "Eoliths from South and South-West England": Geol. Mag., Dec. IV, Vol. X, pp. 102–10, Pls. VI–VIII.
"Late Keltic Cemetery at Harlyn Bay (Cornwall)": Trans. S.E. Union Sci. Soc., 1903, pp. 1–6, figs.
"Pleistocene Non-marine Mollusca, Portland Bill, and Holocene Non-marine Mollusca from various localities": Proc. Malac. Soc., pp. 317–19.
1904. "New species of Non-marine Shells from Java and new species of *Corbicula* from New South Wales": Proc. Malac. Soc., pp. 109–11, pl. vi.
"New variety of *Planispira zebra*, Pfr., from the Island of Gisser, and new species of *Chloritis*, Java": Proc. Malac. Soc., pp. 191–2, pl. xi.
1905. "Notes on land and freshwater shells from the Alhambra Ditch, Granada, Spain; on recent land shells, Carmona, Province of Seville; and on land, fresh-water, and marine shells from Holocene deposits, Carmona": Proc. Malac. Soc., pp. 309–13.
"Pleistocene and Recent Shells from Crete": Proc. Malac. Soc., pp. 307–8.

Some materials towards the History of Wisley and Pyrford Parishes. pp. 80. Guildford.

1906. "Notes on some Microzoa and Mollusca from East Crete": GEOL. MAG., pp. 354–8, Pls. XVIII. XIX.
"Notes on a Holocene deposit at Harlton, Cambs": Proc. Malac. Soc., vii, pp. 85–7.
"Land and Fresh-water Mollusca from Sumatra": Proc. Malac. Soc., 1905, pp. 12–16, pl. ii; 1906, pp. 126–30.

1907. "On the advisability of appointing a Committee for the photographic survey of ancient remains in the British Isles": Rep. Brit. Assoc. Adv. Sci., p. 37.

1908. "Kitchen-Middens in North Cornwall": GEOL. MAG., pp. 140–1.

1909. "Holocene Non-marine Shells of Perranzabuloe": Proc. Malac. Soc., viii, pp. 247–50, 373–4.

1910. "Æolian Deposits on the Coast at Etel": GEOL. MAG., pp. 6–15, 97–101, Pls. IV and IX.
"Pitfalls for Elephants in Africa: in reference to Dewlish": GEOL. MAG., p. 334.
"Notes on (I) Pleistocene, (II) Holocene, (III) Recent Non-marine Shells from Alcudia (Mallorca), and (VI) Non-marine Shells from Manresa (Cataluña)": Proc. Malac. Soc., ix, pp. 118, 122.

1911. "Notes on the Geology of the Bermuda Islands": GEOL. MAG., pp. 385–95, 433–42, Pls. XVIII–XXIII, and Text-figs.

JAMES PARKER, HON. M.A. OXON., F.G.S.

BORN 1833. DIED OCTOBER, 1912.

WE regret to announce the death of Mr. James Parker, of Oxford, at the age of 79. In the leisure of a busy life as a publisher he devoted himself to archæological and geological studies, and accomplished much, especially in the geology of the neighbourhood of Oxford and in the exploration of the caves of Somersetshire. He made a great collection of fossils in the days when the Oolites round Oxford were extensively worked, and some of his finest specimens, including Teleosaurian skulls and Megalosaurian remains, were described in Phillips' *Geology of Oxford*. In 1880 he prepared a map and sections of the strata south of Oxford, which he printed with explanatory notes for an excursion of the Geologists' Association, and in 1884 he issued a revised edition of the same little work under the auspices of the Warwickshire Field Club. His exploration of the caves in the Mendip Hills was done in association with Professor Boyd Dawkins and the late Mr. Ayshford Sanford. Mr. Parker became a member of the Geologists' Association in 1861 and a Fellow of the Geological Society in 1867. He contributed a curiously critical paper on the valley of the Somme and its gravels to the Proceedings of the Association in 1875, and he frequently took part in the discussions at the meetings of both Societies. His views were usually original, not infrequently singular, and he appeared at his best in the informal debates during the excursions of the Geologists' Association, where his genial presence was always especially welcomed.

A. S. W.